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Active Shooter response training environment for a building evacuation in a collaborative virtual environment

Sharad Sharma, Sri Teja Bodempudi
Department of Computer Science
Bowie State University
Bowie, MD 20715, USA
ssharma@bowiestate.edu, *sbodempudi@bowiestate.edu*

David Scribner, Peter Grazaitis
CCDC Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005, USA
david.r.scribner.civ@mail.mil,
peter.j.grazaitis.civ@mail.mil

Abstract

During active shooter events or emergencies, the ability of security personnel to respond appropriately to the situation is driven by pre-existing knowledge and skills, but also depends upon their state of mind and familiarity with similar scenarios. Human behavior becomes unpredictable when it comes to making a decision in emergency situations. The cost and risk of determining these human behavior characteristics in emergency situations is very high. This paper presents an immersive collaborative virtual reality (VR) environment for performing virtual building evacuation drills and active shooter training scenarios using Oculus Rift head-mounted displays. The collaborative immersive environment is implemented in Unity 3D and is based on run, hide, and fight mode for emergency response. The immersive collaborative VR environment also offers a unique method for training in emergencies for campus safety. The participant can enter the collaborative VR environment setup on the cloud and participate in the active shooter response training environment, which leads to considerable cost advantages over large-scale real-life exercises. A presence questionnaire in the user study was used to evaluate the effectiveness of our immersive training module. The results show that a majority of users agreed that their sense of presence was increased when using the immersive emergency response training module for a building evacuation environment.

1. Introduction

Mass shootings are events that occur exceptionally quickly; it is hard for the victim to foresee these events and be prepared for them. The emergencies can occur in various locations that may include educational campuses, religious facilities, workplaces, shopping malls, movie theatres, or nightclubs, in addition to government buildings and military installations [1]. It makes it extremely hard for members of the community to know how to deal with such situations. Human psychological factors like stress and panic play an important role in emergencies. Human psychological factors like stress and panic play an important role in emergencies. Panic causes irrational behavior among humans during emergency situations. Determining these human behavior characteristics in real-life becomes challenging due to high cost and safety considerations. One possible way is to create a virtual environment that can give a full immersive feel of the situation and allow users to navigate and communicate in the environment. It provides a possibility to include fire and smoke. The main objective of this work is to verify the feasibility of designing and developing a collaborative virtual environment (CVE) and its usability for training security agents as well as building occupants to respond to emergency situations like active shooter events, bomb blasts, and fire and smoke. This paper presents an experimental design approach for gathering real-time data on human behavior and emergency response among a set of participants in an immersive virtual reality environment. It also incorporates a user study to evaluate how the building occupants respond to active shooter situations. It also helps to study and train building occupants in the event of active shooter inside the campus building. The immersive active shooter response training for a building developed using Unity game engine integrating with Oculus Rift S hardware. Figure 1 shows the developed a collaborative immersive environment in VR for active shooter response for the building on campus.

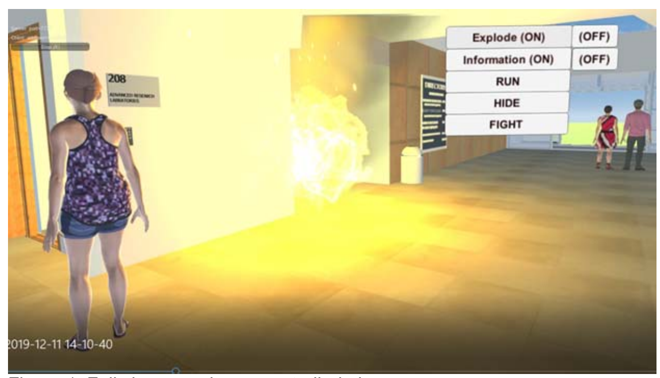

Figure 1. Fully immersed user-controlled player

Over the past decade, VR-based training in emergency response and decision making as well as disaster preparedness has been recognized as a novel alternative to traditional modalities of real-life drills and table-top exercises. During unfamiliar environments, the decision making can be impaired leading to degradation of routinely practiced skills. Active shooter response and training scenarios incorporating real event elements such as large crowds, familiar environments, damaged infrastructure, and visual and auditory cues can better depict the real conditions. If practice makes a person perfect, then emergency response training and exercises are the paths to perfection when it comes to implementing emergency operation plans (EOP) and translating them into action. The CVE platform will help in developing an experimental setup to study human behavior in an active shooter response for decision-making strategies and what-if scenarios. Commercially available game technology has been used for the creation of an experimental setup to model the active shooter response environment and the human characters that make up the crowd. Modeling such an environment is very important these days to respond to emergency situations like active shooter events, bomb blasts, and fire and smoke.

The collaborative immersive environment is implemented in Unity 3D and is based on run, hide, and fight mode for emergency response. The user has an option to enter the CVE as a policeman or as a regular (student, staff, or visitor) person in the building. With continuing advancements in technology, VR-based training incorporates real-life experience and creates a "sense of presence" in the environment, and becomes a viable alternative to conventional training. Thus, immersive collaborative virtual environments offer a considerable advantage over traditional training exercises as it reduces the time and cost to perform real-life drills and tabletop exercises for different what-if scenarios. Our proposed CVE environment allows the users to explore the fully immersive and interactive 3D building model in a realistic VR simulation. Sharma et al. [2,3] have created a CVE for emergency response, training, and decision making in a megacity environment. It includes both user-controlled agents and computer-controlled agents. Artificial Intelligence (AI) agents are computer-controlled agents that include behaviors such as hostile agents, non-hostile agents, leader-following agents, goal-following agents, selfish agents, and fuzzy agents. User-controlled agents are autonomous agents for specific situations or roles such as police officer, medic, firefighter, and swat official.

Lately, due to an increase in active shooter events, there is a need to increase training as well as create public awareness regarding the safety procedures and tactics. Proper training and knowledge on how to respond to active shooter events could decrease or even avoid loss of lives or injuries. Law enforcement officers also need to train for active shooter events with regard to the tactics and protocols to follow in such situations. Deploying such tactics and protocols are beneficial for the evolution of active shooter response training protocols [4]. To best prepare for an active shooter situation, there is a need to create an Emergency Action Plan (EAP), and conduct training exercises. Together, the EAP and training exercises can prepare the occupants of the building to effectively respond and help minimize loss of life. An effective EAP includes:

- A preferred way to report and conduct fire drills for emergencies.
- An evacuation policy and procedure.
- Emergency escape procedures and route assignments (i.e., floor plans of the building, safe zones in the building).
- Contact information for public safety on campus and responsibilities of individuals to be contacted under the EAP.
- Information concerning local area hospitals (i.e., name, telephone number, and distance from the building location).
- An emergency alert notification system to various parties of an emergency.

The rest of the paper is structured as follows. Section 2 briefly describes the related work for CVE, active shooter response, and disaster evacuation drills in CVE. Section 3 describes the implementation of the CVE in three phases. Section 4 presents the simulation and results of the user study, describes the user study setup and the experimental procedures used to run the experiment, offers a post-analysis of survey questions and summarizes the user responses, and discusses the drawn conclusions and proposed future work. Finally, Section 5 states acknowledgments.

2. Related Work

The best EAP in a building includes the occupants in the planning process by ensuring that occupants receive proper training for emergency situations [5]. It should specify what the building occupants must do during emergencies, where the safe zones are located, and worst-case scenarios. Sharma et al. [6,7] have used multi-agent systems for emergency evacuations to model human behavior during emergency evacuations using intelligent agents. They have shown 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. Their study [7] includes the implementation of adaptive and learning behavior for agents using neural networks, genetic algorithms, and fuzzy logic. Moreover, Sharma et al. [8-12] have incorporated a goal-oriented artificial agent-based model to incorporate human behavior parameters. Their study includes emergent human social behaviors such as queuing and herding behaviors.

The understanding of human behavior is critical in evacuation drills and emergency response for decision making for fire events [13]. Chovaz et al. [14] have depicted a model that can be used to understand an active shooter incident [9] during mass shootings. Active shooter incidents lead to mass casualty events [15] and it becomes important to learn from previous disasters and past experiences [16]. The planning stage for active shooter events sometimes involves web-based training [17] as well as analysis for policy options based on agent/computer-based modeling [19]. The training helps the occupants of the building to protect themselves and other people [18]. Agent-based models for civilian response strategies have also been studied for active shooter events [20]. This also incorporates modeling and planning the shooting event and strategies on how to escape [21]. According to the active shooter response training manual [22], it becomes imperative to understand the motive of the person and avoid any issues that may make it extremely hard to get to know and find the best interventions. Simulation-based training on site becomes a good alternative for training the building occupants because people can relate themselves with the real-time with the real-world environment [23, 24]. However, Lewis [25] has stressed that EOP should involve a multi-faceted approach for active shooter training.

Sharma et al. [26] have incorporated immersive VR as a training and education tool for emergency response. They have conducted virtual evacuation drills for an aircraft evacuation [27], a building evacuation [28], a subway evacuation [29], a megacity evacuation [3], a university campus evacuation [30], and a virtual city disaster preparedness and emergency response training [31]. Predicting a person's behavior in an emergency situation is very hard as it involves making quick decisions in response to emotional behavior, crowd behavior, and level and type of emergency.

3. Implementation of Collaborative Virtual Environment (CVE)

The CVE was designed using 3DS Max and Google SketchUp, and programmed with a Unity 3D gaming platform. The CVE environment makes use of a photon network asset in Unity 3D that enables cloud connectivity and multi-user capability. With cloud connectivity, the participant can connect with other participants. The CVE can be used for both immersive and non-immersive environments. In non-immersive environments, participants are able to navigate to their goals using a desktop computer, mouse, and keyboard. In the immersive environment, the participants wear an Oculus Rift S head-mounted display (HMD) and interact with the environment using Oculus Rift controllers. Figure 2 shows a user-controlled agent entering the CVE. The user can use the oculus rift controller to trigger a laser beam for selecting the menu item.

Figure 2. A user controlled agent using Oculus Rift S HMD and its controllers in CVE

The implementation of the active shooter CVE was done in three phases.

3.1 Phase 1: Modeling

Phase 1 of the active shooter CVE consisted of modeling the computer science building on campus using 3DS Max and Google Sketch-Up. The environment was modeled to scale and imported real-time textures. The environment included adding 3D models of furniture in office rooms, labs, and lecture halls such as tables, computers, mouse keyboards, etc. Figure 3 shows the scene view of the first floor of the building in Google Sketch-Up.

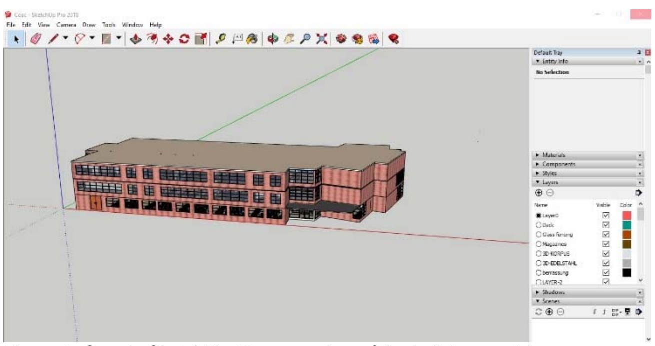

Figure 3. Google SketchUp 3D scene view of the building model

3.2 Phase 2: Exporting to Unity 3D and Photon Cloud Setup

In phase 2, the environment was exported from Google SketchUp to Unity 3D gaming engine. Initially, Unity 3D's tools for animating avatars were utilized to give each agent in the environment functionalities necessary to navigate in the environment. These functionalities included walking, running, and jumping. Also, multiple C# scripts were added to the avatars for giving them the ability to make decisions based on the triggers in the environment. In addition, C# scripts were added to the user-controlled agents in order to give users the ability to communicate with the menu and laser pointer for selection as shown in Figure 4. Similarly, C# scripts were added for implementing a Photon server/client networking system that allows multiple users to collaborate and communicate with one another. The users are able to create a room on the server using a unique application ID. Other users/clients are also able to join the room to participate in the active shooter response environment for campus building. The photon network in Unity 3D makes it possible for all users to view and interact with other user-controlled agents in real time.

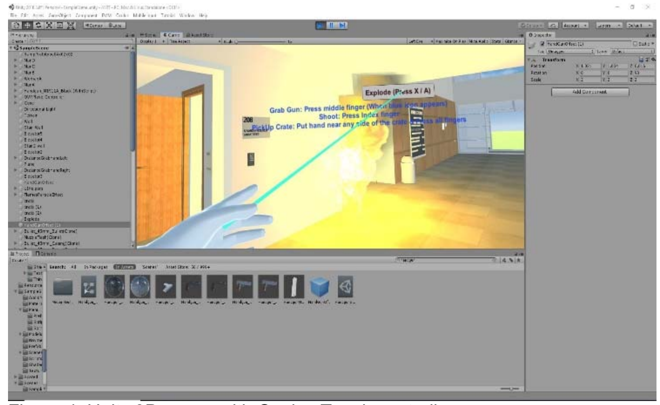

Figure 4. Unity 3D scene with Oculus Touch controller

3.3 Phase 3: Oculus integration and controller hand simulation

In phase 3, C# scripts were developed to integrate Oculus Rift S and the Oculus Touch controllers in the environment. The users were able to navigate in the environment and interact with objects. The Oculus Touch headset allowed users to navigate and experience the environment with full immersion. Oculus Touch controllers give haptic feedback to the user when using objects such as guns and the selection laser pointer.

4. Simulation and Results

The objective of this work was to develop a CVE that serves as a platform for performing evacuation drills and training for building occupants in response to active shooter events. This approach is identified as cost-effective and convenient in VR environments as compared to real-world evacuation drills. Multiple users are able to immerse themselves in the virtual environment; interact with one another; and train on how to respond to active shooter events using the run, hide, and fight option for what-if scenarios. Photon cloud was tested with a size of 10 clients running at the same time in the non-immersive environment. On the other hand, photon cloud was tested with two clients integrated with Oculus Rift S in the immersive environment.

4.1 Run, Hide, and Fight

This work presents an immersive CVE for performing virtual building evacuation drills and active shooter training scenarios using Oculus Rift HMDs. The immersive collaborative VR environment also offers a unique way for training in emergencies for campus safety. The CVE is based on run, hide, and fight mode for active shooter response.

1. RUN and escape, if possible
   - Getting away from the shooter or shooters is the top priority.
   - Leave your belongings behind and get away.
   - Help others escape, if possible, but evacuate regardless of whether others agree to follow.
   - 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 very quiet.
   - Silence all electronic devices and make sure they will not vibrate.

  - Lock and block doors, close blinds, and turn off lights.
  - Stay in place until law enforcement gives you the all clear.
3. FIGHT as an absolute last resort.
  - Commit to your actions and act as aggressively as possible against the shooter.
  - Be prepared to cause severe or lethal injury to the shooter.
  - Throw items and improvise weapons to distract and disarm the shooter.

Active shooter response for run is shown in Figure 2, the response for hide is shown in Figure 5, and the response for fight is shown in Figure 6. The user is able to use the laser pointer triggered through the Oculus Touch controllers to use the menus in the CVE. The menus (as shown in Figure 6) help the user to trigger an explosion as well as get help regarding the user controls. Fire and smoke give the feel of a disaster situation. Using Oculus Rift, users are able to immerse themselves and communicate with one another. The user is able to grab a gun or grab objects to throw at the active shooter as shown in Figure 6.

Figure 5. Active shooter response for hide


Figure 6. Active shooter response for fight

4.2 User Study

Based on our immersive active shooter response training module, a limited case study was conducted. There were a total of 10 users who participated in the study. Participants wore the Oculus Rift S HMD and received instructions on how to use the controllers to navigate within the virtual environment. Following this, participants were asked to interact with the environment using a menu in the environment and a laser beam triggered through the Oculus Rift controllers. Below are the questions that were asked of the participants. A presence questionnaire (PQ) with 15 questions in the user study was used to evaluate the effectiveness of our immersive training module. Table 1 shows the questions that were asked of the participants. The survey allowed the participants to answer questions on a 7-point scale. The general representation of the numbers had 1 being bad, 7 being good, and 5 being average. For the most part, the responses generally stayed in a bracket. The highest value within the bracket changed. There were exceptions to the rule where the numbers were scattered around the graph.

Table 1: PQ for Immersive Active Shooter Response Training

Question Number	Question	Most Common Score	Mean
Question 1	How responsive was shooting with gun in the environment?	4, 5, 6	5.8
Question 2	How responsive were the other actions (AI pathfinding, explosion)?	5, 7	6
Question 3	How compelled were you to grab objects in the environment?	5	5.3
Question 4	How often were you able to predict the response of each button press (after figuring out what button does what)?	7	5.5
Question 5	How often were you able to predict the response to each grabbing option?	5, 6, 7	5.7
Question 6	How well could you search the environment with just your vision?	6,7	6.2
Question 7	How realistic were your movements (similar to walking) in the environment?	6	6
Question 8	How realistic was grabbing objects in the virtual environment?	4, 5, 6	5.2
Question 9	How realistic was using the gun in the virtual environment?	7	6
Question 10	How connected did you feel to the virtual world (how realistic was the environment)?	5, 6	5.5
Question 11	How quickly did you get used to movement and actions?	5, 6	5.5
Question 12	How much control did your actions have on the environment?	5, 6, 7	5.8
Question 13	How often did you get the outcomes when you wanted?	5, 6	5.4
Question 14	At the end of the experience, how proficient were you at moving and performing actions?	6	6
Question 15	How much did your actions interfere with other actions (Touch controllers interfering with other things)?	6	6

The user was able to grab the gun that had a capacity of 10 rounds. This can be fired in 10 seconds before the magazine can be reloaded. However, the shooter had an unlimited number of magazines that can be used to shoot in the CVE. The effective range of the firearm was 50 m. It means that the shooter with an accuracy of 100% will hit 50% of all targets all the time. In this regard, the accuracy of the shooter was 0.8, and this was out of 1.0. One of the important takeaways from the survey was that the participants felt the movement (walking in the environment) of the users and the ability to grab objects (to throw at the active shooter) were realistic. This is shown in Figure 7 as Q7 and Q8. This shows that the participants felt immersed in the environment and the simulation did a good job at capturing an important aspect of the job.

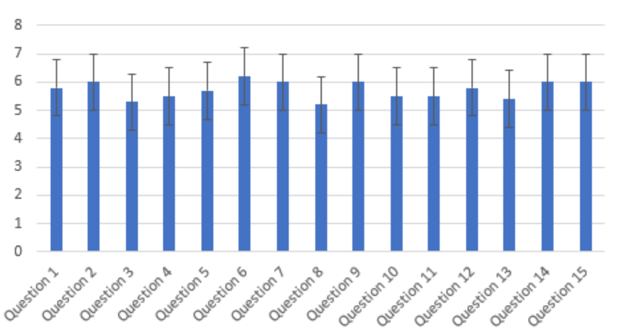

Figure 7. User study responses

The second important takeaway is how the participants felt about their responsiveness to actions such as AI pathfinding, explosions, and menus. The participants felt that those aspects were either really responsive or just responsive. That can be interpreted in many different ways. The participants could have felt that one of the two actions was more responsive than the other or both could have been average. The results for this question are shown as Q2 in Figure 7. The final takeaway was that generally the buttons and menus were simple enough to understand in terms of function and response. The results for this question are shown as Q15 in Figure 7. Thus, the results show that a majority of users agreed that sense of presence was increased when using the immersive emergency response training module for a building evacuation environment.

5. Conclusions

Our proposed CVE can be used for training security agents as well as to conduct emergency response training for building occupants based on run, hide, and fight mode. We have presented a hybrid (human-artificial) platform where experiments for active shooter response can be conducted using computer-controlled (AI) agents and user-controlled agents. We hope our proposed CVE will help in conducting training for active shooter response and what-if scenarios that are difficult to model in real life. The developed CVE can also act as a training and educational tool for decision-making strategies during an emergency response. The user-controlled agents were able to enter the CVE environment using Oculus Rift S and were able to respond to emergency situations like active shooter events, bomb blasts, and fire and smoke. This platform can be fully immersive with the use of Oculus Rift and Touch controllers or can be a non-immersive desktop version with the use of mouse and keyboard. Most people felt that triggering the fire/explosion and movement of user in the CVE was realistic as the average score was 6. This is shown in Figure 7 as Q7, Q14, and Q15. In conclusion, this CVE can act as a training platform that allows emergency response officers and civilians to communicate with one another in order to carry out tasks to follow protocol in an active shooter response situation. The emergency response training and exercises are the paths to implementing EOP and translating them into action.

Acknowledgments

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Author Biographies

Dr. Sharad Sharma is a Professor in the Department of Computer Science, Bowie State University, Bowie, MD 20715 USA. He has received a Ph.D. in Computer Engineering from Wayne State University, Detroit, MI, USA in 2006 and an M.S. from University of Michigan, Ann Arbor, MI, USA in 2003. Dr. Sharma is the Director of the Virtual Reality Laboratory at the Bowie State University. His research focus is on modeling and simulation of multi-agent systems for emergency response and decision-making strategies. His work is motivated by the need for research in real-time agent navigation for reaching a goal in emergency situations like evacuation. His proposed human behavior system integrates both artificial intelligence and fuzzy logic parameters.

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

Dr. David R. Scribner has worked at the CCDC Army Research Laboratory's Human Research and Engineering Directorate (HRED) for over 25 years and earned his Ph.D. in 2013. He has worked in the Weapons Branch at Redstone Arsenal, Alabama and the Dismounted Warrior Branch, both within the Soldier Performance Division. He is currently working within the Complex Ground Systems and Operations Branch of the Soldier Battlefield Integration Division. His research was primarily focused on cognitive workload and multi-tasking in several domains including teleoperated and robotic systems, and marksmanship performance.

Dr. Peter J. Grazaitis has worked at the CCDC Army Research Laboratory's Human Research and Engineering Directorate (HRED) for over 30 years and has worked to advance Army logistics and field logistics planning systems for much of his career. He has assisted with fielding various logistics programs for ammunition, petroleum, water, and other logistical commodities for the Combined Arms Support Command. Dr. Grazaitis has also recently received the prestigious Tibbets Award for his numerous Small Business Innovative Research (SBIR) work in promoting innovative technologies. He is now the manager of the human dimension area of the Dense Urban Environment program at HRED.