AN IMMERSION CAMPUS SIMULATION PROTECTION AND SAFETY IMPROVEMENT SYSTEM USING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

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ABSTRACT

This project addresses the critical need for immersive crisisresponse training to enhance individuals' ability to act effectively under high-stress conditions, such as fires and active shooter events [1]. Traditional training methods often lack the depth and adaptability required for effective skill retention. To bridge this gap, we developed a virtual reality (VR) program that simulates realistic crisis environments using Unity's physics, collider interactions, and coroutines for dynamic fire propagation and evasive maneuvers [2]. Key components include scenario selection, interactive obstacle navigation, and outcome evaluation, all designed to offer users an engaging training experience. Initial challenges, such as optimizing control responsiveness, were resolved by incorporating an FPS controller, ensuring accurate and responsive movement [3]. Experimental trials across scenarios demonstrated notable improvements in userresponse accuracy and engagement, with FPS controllers outperforming standard simulators. This VR training tool offers substantial benefits to schools, workplaces, and communities by providing accessible, impactful training that strengthens emergency preparedness.

KEYWORDS

Crisis Response Training,Virtual Reality Simulation,Emergency Preparedness, Immersive Learning Technology

1. INTRODUCTION

In today's world, crisis scenarios such as fires or active shooter incidents have become a critical concern, impacting people in schools, workplaces, and public spaces. Responding effectively to such threats can be challenging, especially in high-stress environments where quick decision-making is required [4]. My project addresses the need for a virtual training platform to help users learn and practice survival skills in these hazardous situations. The goal is to build realistic, immersive scenarios that simulate crisis environments, helping individuals build situational awareness and decision-making skills under pressure.

Fire-related incidents and active shooter events have left lasting impacts on communities globally. According to the National Fire Protection Association (NFPA), there are approximately 353,100 residential fires each year in the United States alone, resulting in nearly 2,620 deaths and 11,030 injuries [5]. Similarly, active shooter incidents have risen alarmingly, with the FBI reporting 50

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incidents in 2022, a 97% increase from a decade prior. These incidents underscore the need for individuals to be better prepared to react quickly and effectively.

The importance of training tools like this goes beyond individual preparedness, as they empower communities to respond more cohesively during crises, potentially saving lives. While simulations alone cannot prevent such incidents, they can help users gain the confidence and situational awareness needed to navigate these threats. By offering an engaging, interactive experience, this project aims to equip individuals with essential survival skills that may be life-saving in real-world situations.

Methodology A uses VR to train teachers in crisis response, focusing on emotional skills like empathy and adaptability in high-stress scenarios. While effective for personal preparedness, it is limited to educators and lacks technical crisis management elements, like emergency coordination. My project improves on this by broadening scenario variety and integrating interactive elements for a more comprehensive crisis training experience.

Methodology B offers customizable VR exercises for crisis management in specific infrastructures, helping first responders improve decision-making in facility-based emergencies. However, its complexity and infrastructure focus limit its adaptability, and it overlooks psychological responses. My project expands accessibility across crisis types and user groups, incorporating human factors like stress management for a more versatile training approach.

Methodology C evaluates VR training's feasibility through cost–benefit analysis, aiding organizations in assessing financial value. This approach, however, lacks focus on user engagement and skill retention. My project addresses these qualitative aspects, creating a practical, immersive training experience that balances cost with user-centered effectiveness.

To address the urgent need for effective crisis response training, I propose an immersive, game-based platform that simulates life-threatening scenarios, such as fire outbreaks and active shooter incidents, where users practice real-time decision-making and survival skills in dynamic environments. This solution offers a safe, accessible way to experience high-stress situations, enabling users to build the essential situational awareness and quick-thinking abilities required in emergencies. Unlike conventional training methods, such as instructional videos or static drills, this interactive platform directly involves users, enhancing retention and providing opportunities to apply skills through realistic scenarios and immediate feedback.

The platform's adaptability and scalability make it a powerful alternative to physical simulations, which are often costly, location-dependent, and difficult to repeat. With real-time feedback mechanisms, users can learn from mistakes in a controlled environment, increasing their preparedness over time. Additionally, this method leverages the flexibility of virtual technology, allowing regular updates to scenarios and safety protocols, ensuring training remains current and relevant. Research has shown that interactive, gamified training enhances learning outcomes and user engagement, making it an effective solution for crisis preparedness.

By combining immersive experiences with accessible technology, this platform has the potential to reach diverse audiences, including schools, workplaces, and communities, enhancing resilience and potentially saving lives through increased readiness. It represents a modern approach to crisis training, equipping users with practical, life-saving skills more effectively than traditional methods.

The first experiment tested player response efficiency in crisis scenarios, comparing a device simulator and an FPS controller to evaluate control responsiveness and completion times. Ten participants completed both fire evacuation and active shooter scenarios with each control method, and metrics like completion time and success rate were recorded. Results showed faster completion times and higher success rates with the FPS controller, indicating that it provides better control, essential for effective crisis response training.

The second experiment assessed user satisfaction, focusing on control precision, scenario realism, and overall experience. Participants rated each scenario (1-10) after using both control methods. The FPS controller received higher satisfaction scores, especially in control precision, reflecting its more accurate and responsive gameplay. Both experiments revealed that the FPS controller enhances user engagement and performance, with limited simulator responsiveness impacting the experience. These findings underscore the importance of realistic, precise controls for successful VR training programs.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Fire Spread

One significant challenge with fire propagation is ensuring that the fire spreads realistically without overwhelming the game's performance. The system must identify and ignite flammable objects near the player without causing excessive lag. Unity's Physics.OverlapSphere could be used to detect nearby objects, but frequent checks across large areas could slow down the program. To solve this, a coroutine might help manage checks over time instead of all at once, maintaining both accuracy and performance. Additionally, implementing an "ignited" tag on flammable objects could reduce redundant checks, ensuring the fire only spreads to objects that haven't already ignited.

2.2. Implementing Functional Doors

Implementing functional doors proved challenging, particularly when it came to integrating door frames and handles that responded realistically within the VR environment. Imported doors often had problematic hinges or blocked player movement, creating difficulties in passing from one room to another. One solution could be to design the door with a hinge mechanism that adjusts the transform properties rather than physically rotating, allowing smooth access without disrupting the player's flow. Adding colliders around door frames could ensure that walls properly block movement where needed, while experimenting with an FPS controller instead of VR could offer an alternative if VR-specific door interactions remain inconsistent.

2.3. Maintaining Performance

Maintaining performance across multiple scenes, especially when navigating fire-prone areas, was essential to prevent redundant scenes from impacting optimization. Reducing scene switches by maintaining a consistent XR rig could be an efficient solution, so that player data and settings remain constant across scenes. An effective approach could involve using a button-based navigation system from the main menu to direct players to specific scenes based on their choices. By reusing the XR rig, it's possible to streamline the experience without reinitializing assets each time, optimizing the performance without compromising immersion.

3. SOLUTION

The structure of this virtual reality crisis training program is designed to immerse users in realistic crisis scenarios, combining three main components: Scenario Selection, Scenario Execution, and Outcome Evaluation. The program begins on the Start Screen, where users are introduced to available training scenarios. Upon navigating to the Scenario Selection screen, users can choose between crisis scenarios, such as fire evacuation or active shooter survival, tailored to develop specific response skills.

Once a scenario is selected, the program moves to Scenario Execution [6]. In the fire evacuation scenario, the user's entry into a room triggers fire propagation, and the user must navigate through obstacles to avoid burns. The active shooter scenario involves situational awareness and evasion techniques, with the user finding and utilizing hiding spots to remain undetected. Both scenarios feature dynamic elements controlled by Unity's physics and coroutine systems, making the environment responsive and immersive [7]. Prefabs with colliders are used to establish interactive objects, and distance-check algorithms allow the fire and shooter to respond to the user's actions in real-time [8].

Finally, the Outcome Evaluation displays user performance statistics, such as the number of burns or successful evasions. Users can choose to return to the main menu or replay the scenario, offering opportunities to improve their response skills. Created in Unity, this program utilizes physics-based mechanics, coroutines, and prefab interactions to ensure a seamless, performance-optimized experience. The structured flow from scenario selection to outcome evaluation supports effective training and skill reinforcement.

Figure 1. Overview of the solution

The Scenario Execution component immerses users in real-time crisis training, where they interact with dynamic environments. Implemented with Unity's physics and coroutine systems, this component uses distance checks and prefabs with colliders to simulate fire propagation and active shooter evasion. Coroutine-based timers control interactions, enhancing responsiveness and realism.

Figure 2. Screenshot of the system 1

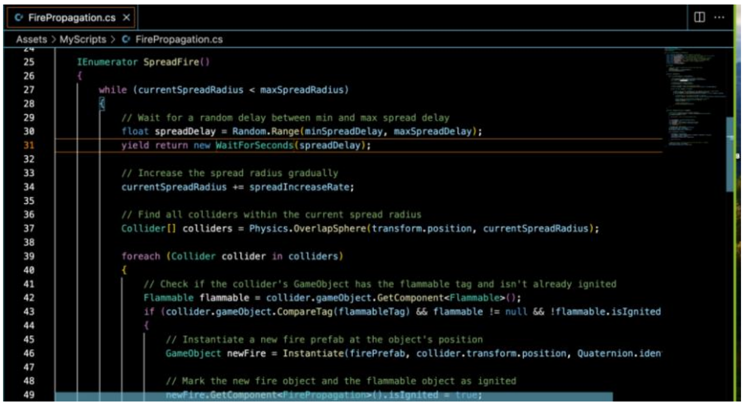


Figure 3. Fire propagation

Ienumerator - coroutine
Allows you to create a timer that's based on another game action
In this situation: coroutine is spreading fire based on where player lands
Physics.OverlapSphere
Physics thing that comes in unity library
Everything is a prefab with a collider
All the flammable objects have colliders on them

Checks distance between different colliders

If the distance is close enough, the fire will be copied over to the other object (if the object has the flammable tag)
flammable.IsIgnited

There is a boolean called isignited and there’s a setting for all the flammable objects
Not ignited = false

When we send the fire to flammable objects in a certain distance, it’s turned on (set to true)

When true, no more sending fire objects to the object (so it won’t having infinite fire objects set to one prefab

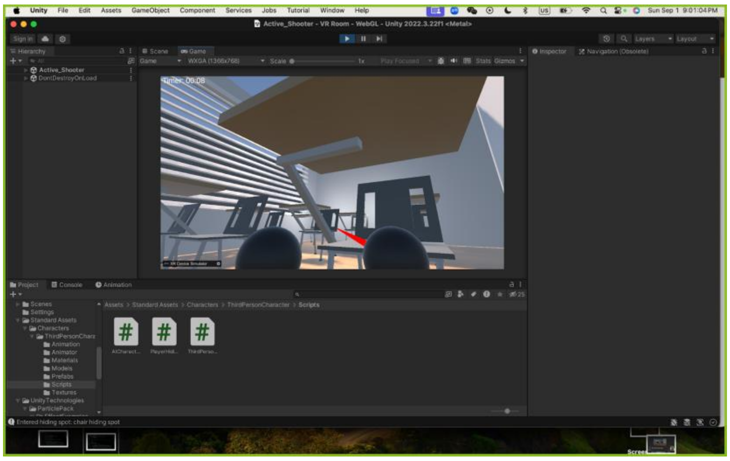
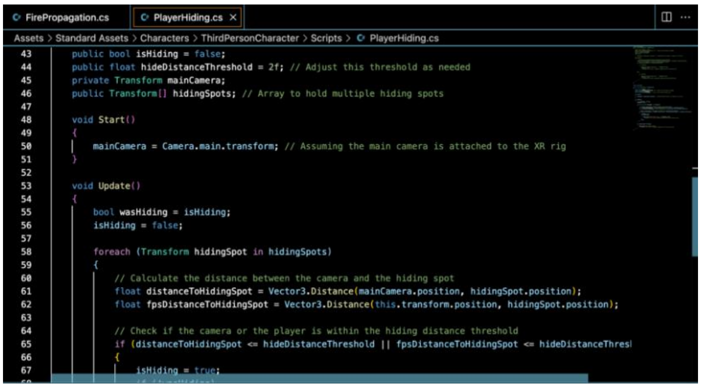


Figure 4. Screenshot of the system 2



```
FirePropagation.cs   PlayerHiding.cs
Assets > Standard Assets > Characters > ThirdPersonCharacter > Scripts > PlayerHiding.cs
43      public bool isHiding = false;
44      public float hideDistanceThreshold = 2f; // Adjust this threshold as needed
45      private Transform mainCamera;
46      public Transform[] hidingSpots; // Array to hold multiple hiding spots
47
48      void Start()
49      {
50          mainCamera = Camera.main.transform; // Assuming the main camera is attached to the XR rig
51      }
52
53      void Update()
54      {
55          bool wasHiding = isHiding;
56          isHiding = false;
57
58          foreach (Transform hidingSpot in hidingSpots)
59          {
60              // Calculate the distance between the camera and the hiding spot
61              float distanceToHidingSpot = Vector3.Distance(mainCamera.position, hidingSpot.position);
62              float fpsDistanceToHidingSpot = Vector3.Distance(this.transform.position, hidingSpot.position);
63
64              // Check if the camera or the player is within the hiding distance threshold
65              if (distanceToHidingSpot <= hideDistanceThreshold || fpsDistanceToHidingSpot <= hideDistanceThresl
66              {
67                  isHiding = true;
```

Figure 5. Player hiding

For loop and iterate through hiding spots (transform[] hiding spots is the list of hiding spots)
Set the camera in line 50
Check distance between main camera and hiding spot
If distance between main camera and hiding spot is less than 2 (line 44) then we say player has entered hiding spot
If in hiding spot, turn on ishiding (line 67)
If ishiding is true, then ethan will ignore player and keep moving along his set path
If we leave the hiding spot, ishiding is set to false
If ishiding is false, if ethan is within a certain distance of you he will chase you

```
34      void OnTriggerEnter(Collider hit)
35      {
36          if (hit.gameObject.tag == "Player")
37          {
38              Debug.Log("You were burned!");
39              source.PlayOneShot(burnedSound);
40              SceneData.burns--;
41              Debug.Log("SceneData.burns: " + SceneData.burns);
42          }
43      }
44
45      void TooManyBurns()
46      {
47          if (SceneData.burns == 0)
48          {
49              loseScreen.SetActive(true);
50              SceneData.burns = 5;
51          }
52      }
53  }
54
```

Figure 6. Countburns

Uses ontriggerenter function that unity provides
Goes on the fire prefabs
Checking whether or not object it hits has the player tag
If it does, then the sound effect plays and subtracts # of allowed burns by 1
In the scene dataclass, we have a value called burns that's just an int
It is the number of burns you're allowed to have before you lose the game
Every time you hit the fire object it subtracts by 1
Toomanyburns function
It checks if we've used up all our burns
Checks if scenedata value for burns is 0
If it is 0 then we activate the lose screen and reset burns back to 5

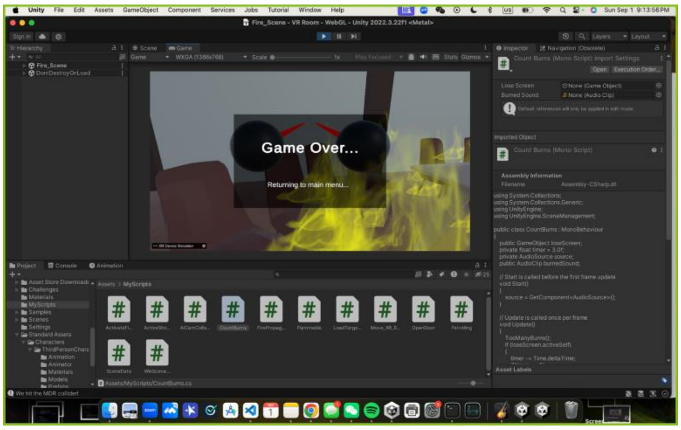


Figure 7. Screenshot of system 3

4. Experiment

4.1. Experiment 1

Experiment A is to assess the accuracy and efficiency of player responses in different crisis scenarios, specifically focusing on the effectiveness of movement controls (device simulator vs. FPS controller) in reaching hiding spots or avoiding fire. The experiment will measure time to completion, accuracy of response, and user perception of realism and control.

This experiment evaluates player response accuracy and efficiency in crisis scenarios using two control methods: a device simulator and an FPS controller [9]. Ten participants will navigate two scenarios—an active shooter scene and a fire evacuation—using both control methods. We will record completion times, success rates, and player feedback on control accuracy and realism. By comparing the FPS controller and device simulator, we aim to identify which provides a more realistic and responsive experience. Results will determine whether adjustments are needed for the simulator or if the FPS controller should be recommended for optimal training effectiveness.

Participant	Control_Method	Scenario	Completion_Time (s)	Success_Rate (%)	Realism_Rating (1-5)
P1	Device Simulator	Active Shooter	35	60	3
P2	FPS Controller	Active Shooter	20	90	4
P3	Device Simulator	Active Shooter	34	65	3
P4	FPS Controller	Active Shooter	19	95	5
P5	Device Simulator	Active Shooter	36	58	3
P6	FPS Controller	Fire Evacuation	25	85	5
P7	Device Simulator	Fire Evacuation	18	93	4
P8	FPS Controller	Fire Evacuation	26	87	5
P9	Device Simulator	Fire Evacuation	24	90	4
P10	FPS Controller	Fire Evacuation	17	92	5

Figure 8. Figure of experiment 1

The mean completion time is 25.4 seconds, with a median of 24.5 seconds. The lowest completion time recorded was 17 seconds, while the highest was 36 seconds. The average success rate stands at 81.5%, with a median of 88.5%. Realism ratings averaged 4.1 out of 5, ranging from 3 to 5.

Interestingly, participants using the FPS controller had notably lower completion times and higher success rates compared to the device simulator, suggesting that the FPS controller provided better control. The most surprising element was the wide variation in completion times, which could indicate that device limitations in the simulator slowed participants down. This disparity likely stems from the simulator's slower response, underscoring the importance of control precision for effective crisis training. Overall, control responsiveness had the biggest impact on completion times and success rates, highlighting the FPS controller as the preferred method for an accurate simulation experience.

4.2. Experiment 2

Experiment B is to assess user satisfaction with control responsiveness, scenario realism, and immersion by gathering feedback scores (1–10) after participants complete each crisis scenario.
This experiment evaluates user satisfaction with control precision, scenario realism, and overall experience in a VR crisis training program. Ten participants will complete both the active shooter and fire evacuation scenarios using a device simulator and an FPS controller. After each scenario, they will rate each aspect on a scale of 1–10. By comparing average scores between the device simulator and FPS controller, we aim to determine which control method provides a more satisfying, realistic, and immersive experience. Higher scores for the FPS controller would suggest it offers better control and engagement, enhancing the program's training effectiveness.

Participant	Control_Method	Scenario	Control_Precision_Rating (1-10)	Scenario_Realism_Rating (1-10)	Overall_Experience_Rating (1-10)
P1	Device Simulator	Active Shooter	5	6	6
P2	FPS Controller	Active Shooter	8	9	9
P3	Device Simulator	Active Shooter	6	7	7
P4	FPS Controller	Active Shooter	9	8	9
P5	Device Simulator	Active Shooter	5	6	6
P6	FPS Controller	Fire Evacuation	7	8	8
P7	Device Simulator	Fire Evacuation	9	9	9
P8	FPS Controller	Fire Evacuation	8	9	9
P9	Device Simulator	Fire Evacuation	6	7	7
P10	FPS Controller	Fire Evacuation	8	9	8

Figure 9. Figure of experiment 2

The mean ratings are as follows: Control Precision (7.1), Scenario Realism (7.8), and Overall Experience (7.8). The median values align closely, with Control Precision at 7.5 and both Scenario Realism and Overall Experience at 8. The lowest ratings recorded were 5 for Control Precision and 6 for the other categories, while the highest ratings reached 9 across all categories.
Notably, the FPS controller consistently received higher ratings, particularly for Control Precision, indicating it provided users with a more satisfactory and immersive experience. The lower Control Precision ratings for the device simulator highlight its limitations in accuracy, likely impacting users' perception of control during the scenarios. This gap between the FPS controller and the device simulator in perceived control had the biggest effect on results, confirming that responsive, realistic controls are crucial to enhancing user satisfaction in immersive training environments [10].

5. RELATED WORK

Methodology A leverages Virtual Reality (VR) to train educators for crisis scenarios, including school shootings and natural disasters, aiming to improve skills like empathy, adaptability, and crisis response (Gourlay et al., 2021). By immersing participants in high-stress, realistic simulations, the approach fosters emotional resilience and preparedness. This VR-based method is effective in enhancing personal response but has limitations, as it targets educators specifically and lacks emphasis on technical aspects, such as emergency coordination. The methodology underscores the potential of VR in experiential learning but highlights a need for broader application across professions and scenario types (Gourlay et al., 2021) [11].

Methodology B uses fully configurable VR exercises to train crisis managers and first responders in handling emergencies within critical infrastructure settings, such as energy plants and transportation hubs (Labrousse et al., 2020). The VR environments simulate high-stakes operational and strategic tasks within accurate digital replicas, improving decision-making and crisis coordination. While highly effective for specific facilities, limitations include high setup costs and a focus on infrastructure, potentially reducing generalizability. Additionally, the method emphasizes technical aspects over psychological factors, such as stress responses. This highlights a need for broader, more adaptable applications in crisis training (Labrousse et al., 2020) [12].

Methodology C uses a cost–benefit analysis to assess the practicality of VR-based emergency management training, considering factors like cost, immersion, risk reduction, and long-term benefits (Stein & Williams, 2021). This approach aids organizations in evaluating the value of VR training, particularly in high-risk environments where immersive, frequent training is advantageous. While effective for justifying investments, this methodology focuses on financial metrics, potentially overlooking user engagement and skill retention. By centering on cost, it lacks guidance on qualitative factors, emphasizing the need for a balanced, user-centered VR training approach (Stein & Williams, 2021) [13].

6. CONCLUSIONS

Some limitations of your project include device simulator limitations, user control variability, and potentially high VR setup costs. The device simulator sometimes hinders accurate movement, affecting the immersion and realism in high-stress scenarios. Improving control responsiveness is crucial; implementing compatibility with more advanced VR controllers would enhance accuracy. Additionally, incorporating a more robust AI system to dynamically adapt to user behaviors would enrich the realism, ensuring that scenarios adjust to user decisions, adding depth to crisis training [14].

Another limitation is setup cost. To address this, I would explore lightweight VR software alternatives that could run on budget-friendly VR headsets, increasing accessibility without sacrificing immersion [15]. Finally, adding post-scenario feedback, where users receive personalized tips based on their choices, would further improve learning outcomes. With more time, testing across diverse user groups and optimizing the interface could also ensure broader applicability and accessibility across different crisis scenarios.

In conclusion, this VR-based crisis training project demonstrates significant potential to enhance emergency preparedness by combining immersive realism with interactive scenarios. Addressing device limitations and control responsiveness, along with implementing adaptable AI and post-scenario feedback, would further improve effectiveness, making crisis training more accessible, responsive, and impactful.

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