Tactical Rescue and Evacuation Simulation in a Multi-Story Building

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***Abstract*—The practice of conducting emergency drills with physical locations creates both expensive and safety risks. A single-user first-person VR simulation takes place within an authentic burning urban plaza for training essential skills that include fire suppression and threat neutralization together with civilian evacuation. A mix of extremely detailed 3D models, realistic particle effect-generated smoke and fire materials, and spatially optimized sound effects leads to this responsive sense of immersion in the training environment. AI-controlled characters make seamless progress through Unity's NavMesh system while various sensor inputs activate functions that include door-destruction and NPC reactions. The application serves as a secure platform for training practices which promotes both experience-based competence and disciplined choices in high-pressure situations. The introduction of our augmented approach produces learning speed improvements with additional participant interest that outweighs conventional methods according to first feedback results. Upcoming development will involve the implementation of features that enable multiplayer functionality together with virtual reality helmets as well as enhancing scenario complexity.**

***Index Terms*—Virtual Reality, Emergency Response Training, Unity3D, Spatial Audio, AI Pathfinding, Simulation**

I. INTRODUCTION

Emergency response teams conduct dangerous and limited by location live drills that also prove highly expensive. Through Virtual Reality (VR) users can conduct safe training without facing actual dangers. The simulation sets the trainee in a high-traffic city plaza where a controlled fire burns at its heart. The training system aims to teach trainees three essential competencies through its main instructional targets.

- Operating a fire extinguisher safely for effective flame suppression forms part of this objective.
- The trained use of a sidearm enables technicians to accurately stop hostile actors while clearing the threat.
- Efficient guidance of trapped civilians to a safe evacuation point.

The fire effects along with the smoke appear in detail because of Unity's particle system. The system distributes directional audio signals with crackling flame sounds and radio transmissions and crowd simulants for collecting decisions. The simulation platform operates across PCs through keyboard and mouse interfaces and mobile devices through their on-screen buttons to serve various training environments. Player proximity detection together with collision sensor triggers real-time warnings through sound effects which also confirm rescue successes after successful civilian saves. Recurrent practice in VR enables personnel to develop automated memory systems and boosted self-assurance that leads to enhanced operational readiness in genuine deployment contexts. The system acquires performance measurement data points which include reaction period measurements in addition to motion precision and route selection data to enable trainers to tailor their educational approach.

II. RELATED WORK

The application of virtual reality technology has completely redesigned training structures throughout different business sectors. Stress levels together with exit time performance improved by 25% when Li and Zhang conducted virtual reality fire evacuation drills rather than conventional drills [1]. Studies conducted by Harris et al. proved that virtual reality-based decision simulations improve the ability to recognize situations during high-pressure conditions [2]. Zhou et al. developed a VR fire safety training program that boosted long-term procedural retention by 30% according to their data [3]. The team of Crosby conducted VR-based shipboard fire drill exercises which proved beneficial across different domains [4]. The analysis of complex environments through behavioral models merged with VR resulted in a combined approach by Lovreglio et al. [5]. Hamed-Ahmed developed a virtual reality-based fire drill for industrial areas through the implementation of multiuser metaverse technology [6]. Smith and Doe produced an evacuation simulator based on virtual reality to enhance both teamwork and information exchange through collaborative systems [7]. Our simulation combines visual and audio with proximity triggers as input triggers from Unity3D to deliver mobile deployment for users.

III. IMPLEMENTATION

A. Modeling Phase

Blender served as the platform which we used to construct the virtual plaza along with all its surrounding buildings, barricades, vehicles and street props. The virtual plaza received realistic materials through PBR textures in each model of concrete metal and glass. The video game implements Mixamo to develop both friendly and enemy characters which receive built-in animation sequences for walking and running and maintaining rest positions.

B. Exporting to Unity

The .glb files exported from Blender got integrated into Unity version 2021.3 LTS. Rigidbodies and mesh colliders received their configurations for doors and extinguishers among other interactive elements. The application uses realistic daytime lights which generate shifting shadows resulting from object movements.

C. Behaviors and Scripts

C# scripts developed to activate fundamental system operations.

- Fire controls the particle effects system while tracking which area the fire has been put out and automatically spreading fire in unattended areas.
- The Gunmechanics detects enemy and door hits by using raycasting to activate damage effects on both targets.
- The NPCAI and NPCFollowTrigger system selects from Idle, Follow and Flee states through sensors that track proximity and threats.
- Voice controller AudioManager acts as the primary mechanism that loads audio tracks into mixer channels and modifies sound volume then locates audio position based on the character's current coordinates.
- Perfectly designed as a system the SceneManager enables menu controls across the interface and handles the display of both HUD elements plus rescue popup windows.

D. User Interaction

FirstPersonController performs both movement operations and manages camera viewing. The user can move through the game using WASD and the mouse on PC and virtual controls on mobile devices simulate these actions. Hazards trigger warning cues through the detection of sphere colliders entering their range. Task completion triggers are displayed through trigger zones including both successful NPC rescue or extinguishing the last fire.

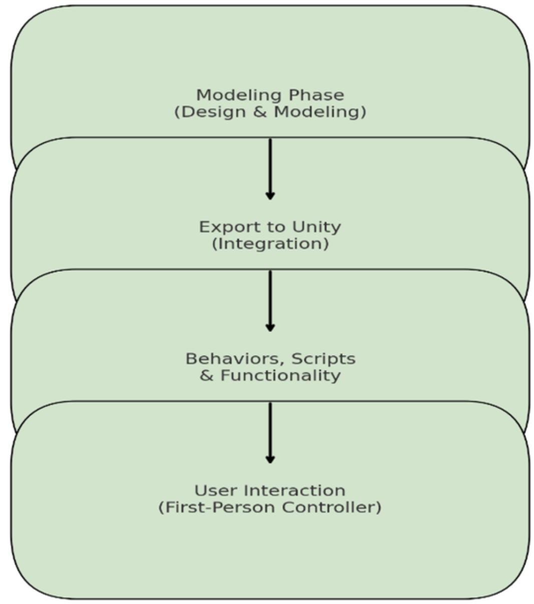

Fig. 1. Overview of Implementation Architecture

IV. FUNCTIONALITY SECTION

This part describes how we defined every required function, based on technical information and trainee perspectives.

A. Vision

In Figure 2. Realistic shaders, together with textures, were implemented on the game assets through Unity's Universal Render Pipeline. The dynamic lighting system produces shadows that move and become more intense according to changes in the fire level. Through particle systems the game creates different smoke density effects and ember lighting effects. Targeted objects receive temporary border highlights when the player aims towards them which assists trainees to identify tools and paths during stressful situations.

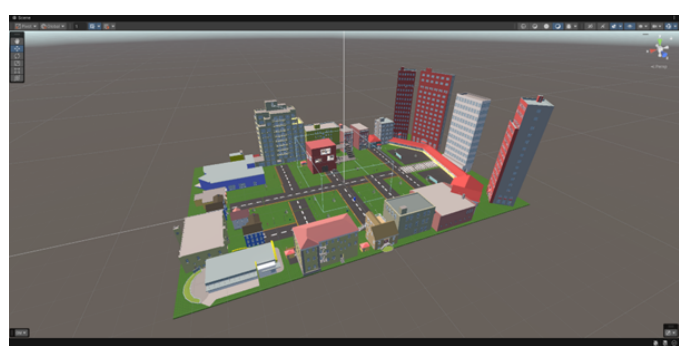

Fig. 2. Virtual environment with buildings, roads and other props

B. Sound

In Figure 3. Multiple AudioSource components with logarithmic roll off distance settings work together to play the spatial audio cues (fire crackle, gunshots, footsteps) for realistic distance attenuation. Multiple instances of stereo background sounds featuring sirens and crowd noises continually loop in the scene. The AudioManager reprograms indoor and outdoor reverb settings while simultaneously increasing sound levels when students near dangerous areas to attract their focus.

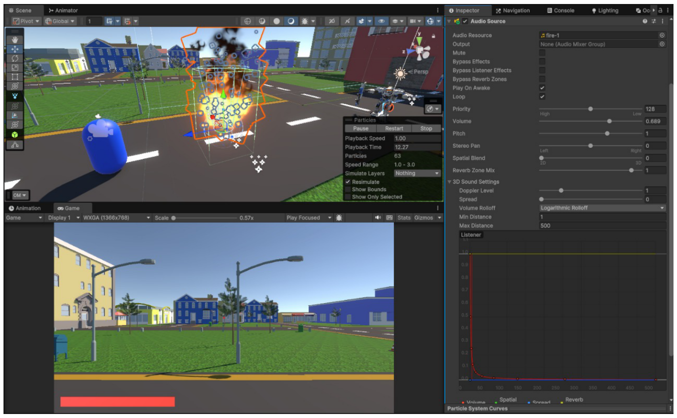

Fig. 3. Audio Manager settings

C. Animation

In Figure 4. all NPC and enemy models sourced from Mixamo accomplish their motion transitions through blend trees when switching between idle and walking and running states as well as reactions. Realistic smoke and fire effects are achieved through layered particles in the animation system whereas realistic motion of moving objects follows predefined paths and splines for better scene dynamics.

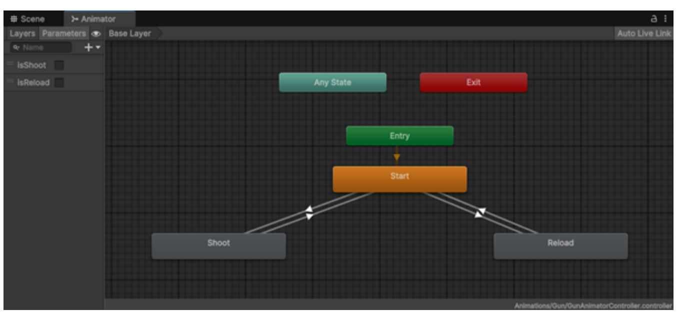

Fig. 4. Animation of the game elements

D. Interactivity

Five user-initiated events enhance engagement:

1) Each time the player hits their targets enemies will react by a hit visual which modifies skinned mesh renderer.
2) The door is destroyed once a hit causes it to destroy.
3) Civilians will follow threat elimination and adjust pace to match the player after threat elimination.
4) The fire suppression system reduces light intensity together with particle emissions in response to foam spray with a visual pressure gauge indicator.
5) After player and civilians move to the safe zone, the game is completed.

E. Characters/Avatars

In Figure 5. The simulation shows non-playable characters as silhouette figures among three different age groups including adults and elderly figures plus children. The enemy avatars within the system use weapons for attacks while displaying hostile behavioral patterns. Each avatar uses collision-based sensors as well as state-driven animations which results in better realism alongside improved trainee immersion.

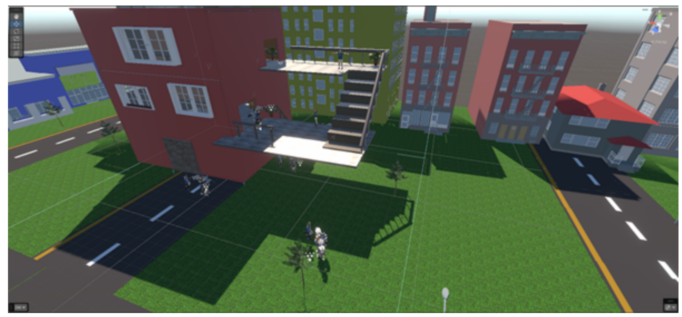

Fig. 5. Non-player character models and behaviors

F. Sensors

In Figure 6. Three sensor types of guide interactions:

- Sphere-shaped proximity sensors trigger audio warnings and reactions.
- Coroutine-based timers schedule siren activations and scenario changes.
- Raycasts detect extinguisher use and projectile impacts for scoring.

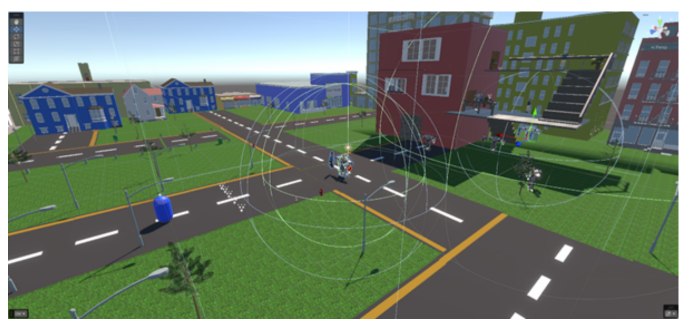

Fig. 6. Activation of hazard warning cues

G. Player Controller

In Figure 7. Unity's FirstPersonController is updated to assist in controlling characters more effectively and enable correct jump and interaction detection. The mobile training platform duplicates computerlike buttons and joysticks through on-screen user interfaces to maintain uniform learning experiences between different systems.

Fig. 7. View of the first-person controller interface

H. AI Implementation

In Figure 8. All AI pathfinding operations use the NavMesh system developed by Unity. We applied baking NavMesh generation along with height map to the entire plaza space for creating both walkable zones and inaccessible areas. AI enemies change their navigation mode from patrol to shoot within the area where they detect targets and civilians continuously replan their routes to bypass obstacles. Several active agents can function effectively because of priority-based path update queues.

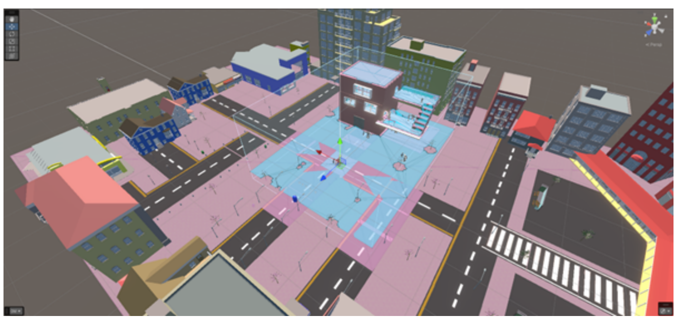

Fig. 8. NavMesh pathfinding visualization

I. Interface Elements

In figure 9 10 . Menus include:
• Main Menu: Play, Instructions, Quit.
• Pause Menu: Resume, Main Menu.

Fig. 9. Main menu screen

Fig. 10. Pause menu overlay

J. Multi-User, Hardware Integration, and Mobile Version

The current version gives Windows 10+ and Android 9+ users the ability to train alone without needing extra hardware devices. The upcoming hardware development phase includes Meta Quest and HTC Vive VR headset compatibility along with mobile joystick hardware integration as an optional feature. The platform will support multiplayer functionality that allows team drills with defined roles such as firefighter and medic.

The program functions properly on both Windows 10+ computers equipped with Intel i5 CPU and GTX 1060 GPU and Android 9+ devices requiring 4 GB RAM and Adreno 506-level GPU. Both the computer version maintains above 60 FPS performance and mobile platforms reach rates above 30 FPS. The simulation functions entirely without requiring any accessory equipment such as joysticks or headset devices.

V. CONCLUSION

The VR simulation delivers an extensive training space that creates deep immersion for emergency service professionals. Through the integration of cutting-edge visualization and real-time audio feedback with sensor-triggered interactions and adaptive AI responses to a dynamic range of conditions, students can hone crucial skills through repeated practice under varied conditions without risking equipment or personnel.

A. Lessons Learned and Limitations

The development of the simulation showed poor performance of rendering high-density particle effects with lower-end mobile devices. The high complexity of NavMesh paths sometimes caused agents to fail in following their designated directions when placed near each other. The job of achieving performance-equilibrium with realistic visuals required us to reduce shader complexity and cut back on nonessential particle effect layers. The available version operates with a solitary user at a time with no features for full VR headset support.

B. Future Extensions

Planned enhancements include:

- The system will allow multiplayer drill participation with specific roles between firefighters and medics and security personnel.
- The system implements OpenXR for headset support that enables both Meta Quest and HTC Vive devices to offer genuine motion-assisted immersion.
- The system should develop more simulation modules that include earthquake simulations and chemical spill incidents together with mass-casualty response scenarios.
- The platform will adjust scenario difficulties using performance data from students to maintain challenging training while remaining attainable.

ACKNOWLEDGMENT

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