Dave: Detection of Anomaly in Virtual Environment

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***Abstract*—This project proposes and develops a virtual reality (VR) application designed to train users to identify anomalies within a complex indoor/outdoor building environment. Traditional anomaly detection training lacks immersive, engaging experiences. This VR environment bridges that gap by simulating realistic emergency scenarios where users interact with AI-driven agents and dynamic objects. It targets safety training, behavioral research, and surveillance simulations. The primary beneficiaries include students, researchers, trainers, and public safety professionals.**

Keywords—anomaly, detection, virtual, reality, application

I. INTRODUCTION

Anomaly detection implies finding unusual patterns or behaviors that deviate from what is normally expected. Identifying and spotting these quickly is important for fast and effective action in areas like emergency response or security. Virtual Reality (VR) is a strong tool for creating realistic, immersive environments, making it perfect for training and testing how well users can detect anomalies. Unlike traditional methods such as lectures or 2D simulations, VR issmmerses users in lifelike 3D environments where anomalies are dynamically embedded in the scene, such as flickering lights, unusual NPC behavior, misplaced objects, environmental hazards (like smoke or fire), or unexpected sounds. The central objective of this project is to develop a comprehensive virtual reality (VR) game that focuses on anomaly detection within intricately modeled indoor and outdoor environments. The simulation is constructed using Unity 3D as the game engine, with architectural and environmental models created in 3Ds Max and SketchUp. The virtual environment includes realistic features like hallways, offices, stairwells, rooms, parking lots, courtyards, and entry areas, closely resembling real-world buildings and public spaces. It also includes smart non-player characters (NPCs) that use AI to move around and interact with users. Players must detect various anomalies—such as out-of-place objects, strange character actions, safety hazards, or subtle visual and sound cues—woven into the interactive gameplay. Environmental sensors such as proximity detectors, timed triggers, and touch-sensitive zones are incorporated to activate events and guide user actions. This VR application is developed primarily for students, emergency response trainees, behavioral researchers, and safety professionals who benefit from experiential learning environments. Users can practice identifying and responding to abnormal situations in a risk-free, highly immersive setting by engaging with the virtual environment.

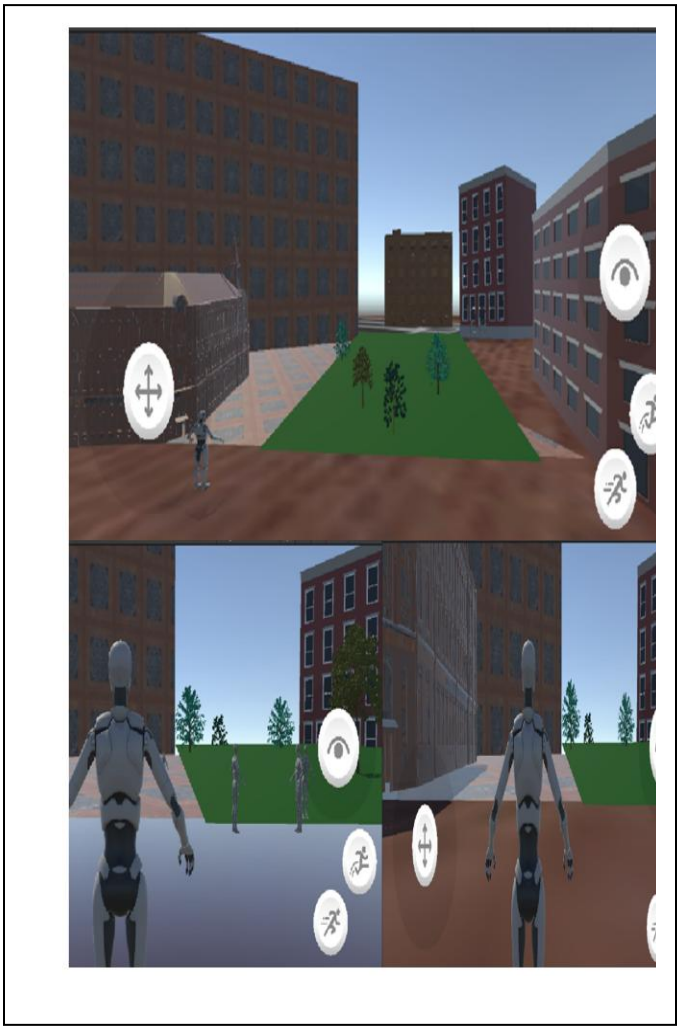

Fig. 1. Overall exterior view of the virtual building environment

II. Related Work

There are many research studies that are related to my work on finding unusual events (anomalies) using virtual reality. Some of these studies show that virtual reality is helpful for improving safety training and teaching people how to act in different situations. Some other studies have shown that training conducted in VR often leads to better situational awareness, better response to actions, and improved performance compared to traditional training methods.. This study classifies the related works into three categories as follows.

A. *VR for Anomaly detection in AI-integrated simulations*

[1] shows that using things like realistic threat simulations, virtual learning environments, and smart AI systems can make training more interesting and effective. Meanwhile, [2] presents a new AI system that can quickly spot unusual activities in the data coming from Internet of Things (IoT) devices. Recognizing the challenges posed by the sheer speed, massive volume, and diverse nature of data produced by IoT devices, much like trying to monitor thousands of rapidly shifting radio signals at once, the framework aims to provide an efficient and adaptive solution.

B. *Immersive learning and emergency simulations using virtual environments*

The main goal of the study in [3] was to see how using immersive virtual reality (VR) in learning simulations changes how students learn and what they remember. The study especially wanted to find out if VR could make learning more interesting (something new to them, easier to understand, and help students remember information better than regular virtual learning). In [4], Radianti, Majchrzak, Fromm, and Wohlgenannt conducted a systematic review analyzing the use of immersive virtual reality (VR) applications in higher education. The study identified key design elements such as interactivity, realism, and user engagement that contribute to effective learning outcomes. Furthermore, the authors proposed a research agenda that encourages future studies to focus on long-term learning effects, accessibility challenges, and the cost-effectiveness of VR technologies in educational settings. In [5], Jensen, Ludwig, San Mateo, Proctor, Patrick, and Wong talked about building smart behavior models for training simulations, especially to deal with enemies that act in unexpected ways. Their work focused on making simulations that can change and react to what the enemy does, helping to create more realistic and challenging training experiences. The study highlighted that incorporating adaptive behaviors can better prepare users for real-world situations by improving decision-making skills, flexibility, and overall readiness.

C. *VR in education for critical thinking and interaction*

In [6], the authors conducted an experiment to see how display settings and scene details affect training for a visual scanning task in a simulated city environment. During training, they changed the field of view and the amount of visual detail, then tested performance using the most realistic settings. They measured how well participants found targets and followed a set strategy. The results showed that a wider field of view helped people find more targets, while a more complex scene made it harder to perform well. In [7], Pellas, Fotaris, Kazanidis, and Wells conducted a systematic review to examine how interactive technologies enhance learning experiences in primary education. Their study highlighted that, using tools like VR and AR can boost student engagement, motivation, and understanding of complex subjects when thoughtfully integrated into the curriculum. Similarly, in [8], Ikhsan, Sugiyarto, and Astuti explored the use of a virtual reality laboratory to foster critical thinking skills among students. Their findings showed that VR environments give students hands-on practice, helping them think more deeply, solve problems, and stay actively involved in learning, which improves their higher-level thinking skills.

III. Implementation

The implementation pipeline begins with the modeling phase, where indoor and outdoor structures are modeled using 3Ds Max. These assets are then exported in FBX format and imported into Unity for further development. In Unity, interaction scripting is carried out to incorporate AI behavior, user interactions, dynamic lighting, and anomaly detection features. This organized process supports a seamless flow from creating 3D models to building a fully interactive VR experience. As shown in Fig. 2: System Architecture Diagram, it maps out each step from initial modeling to final deployment on a mobile device.

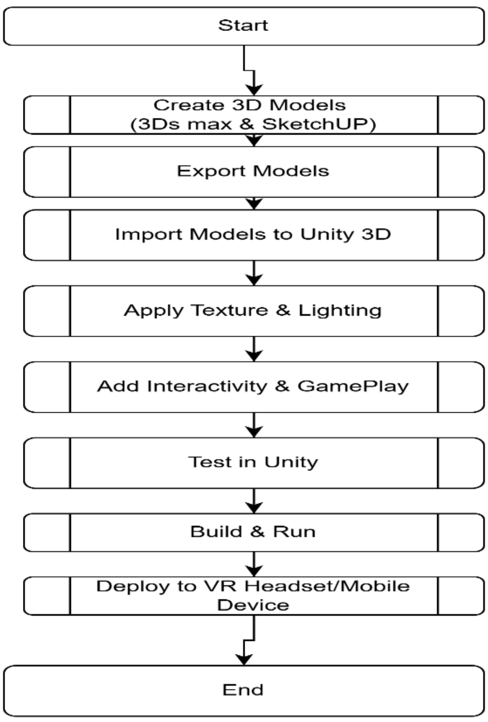

Fig. 2: System Architecture flow Diagram

IV. FUNCTIONALITY

The anomaly detection virtual reality system, in general, is designed to immerse users in realistic indoor environments where they can actively identify and respond to unusual or hazardous situations. The functionality of the system simulates real-time emergency scenarios to test users' awareness and decision-making using interactive features, AI-driven NPC behaviors, and sensor-based triggers. With the developed application, users move around in a realistic 3D virtual space to spot unusual things like strange objects, odd behaviors, or unexpected events. This interactive experience helps users stay engaged and improves their skills in noticing and reacting to possible dangers in real-life situations. This VR system includes the following features:

VR Design Element	Details of what is implemented
1. Vision	- Realistic textures, dynamic lighting, etc., were used. - Visual effects like fire sprawl, sparks, and flickering were used.
2. Sound	- Sound when the player walks-Footstep - Fire Sparkling audio.
3. Animation	- Animated NPCs - Jumping Third-person Player Character.
4. Interactivity	- Player interacts via trigger zones (e.g., approach anomaly to log it). - Left-click to show the tag of detected objects or anomalies. - Touch the screen(for the Mobile version) to move the TP character in the environment.
5. Character Behaviors	- AI NPCs with pathfinding using NavMesh. - Anomalous NPC behavior like erratic walking, standing still in inappropriate zones.
6. Sensors	- Time Sensor: Certain anomalies only appear at specific times. - Touch Sensor: Tag appears when touching objects.
7. Player Controller	- First-Person Controller (FP Character Prefab in Unity). - Movement using joystick or VR controller input.
8.AI Implementation	- NPC AI using Unity's NavMesh Agents and Behavior Trees. - NPCs demonstrate careless behaviors when an anomaly triggers. -Algorithms for Automatic fire activator and detector have been implemented
9. Interface Elements	- On-screen UI: Menu (Play, Instruction, Quit), Icons for Mobile Version - Menus: Start Game, Difficulty Settings, AI Behavior Settings. - Tooltip interactions (object descriptions, hints).
10.Multi-User Environment/ Mobile Version	- Custom Avatars: Mixamo-rigged character models. - Mobile Version: Alternative version with joystick controls and touch pad system

Table 1: Elements of the Virtual Reality design and the details of how they are implemented.

V. CONCLUSION

The developed virtual reality application presents an innovative and immersive approach for training and conducting research in anomaly detection. Created with softwares like Unity 6, 3Ds Max, and google sketchup, it blends lifelike environments with intelligent interactive elements. The application is primarily for students and learners for the enhancement of situational awareness, supporting effective decision-making, and improving user preparedness in emergencies. Some challenges were encountered during development, including performance issues caused by high-polygon models and occasional sensor misfires in specific scenes. Future work will focus on designing an enhanced multiplayer mode application optimized for high-latency networks, integrating enhanced AI through reinforcement learning, and adding realistic smoke and fog simulations to increase environmental complexity and realism.

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REFERENCES

The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] was the first ..."

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