AI-Based 3D Disaster Evacuation Simulation System for Intelligent Disaster Management

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Abstract- Natural disasters such as earthquakes, floods, fires, and structural collapses pose significant risks when evacuation planning is not properly implemented. Traditional evacuation systems rely on static maps and predefined exit routes, which are ineffective in dynamic disaster environments. This paper presents the design and implementation of an AI-based 3D disaster evacuation simulation system developed using Unreal Engine and intelligent pathfinding algorithms. The proposed system simulates real-world building environments and crowd behavior to dynamically generate optimal evacuation routes. The system provides real-time hazard detection, adaptive path recalculation, and performance analysis. This approach enhances disaster preparedness and improves evacuation efficiency in critical infrastructures.

Keywords—Disaster Management, AI Pathfinding, 3D Simulation, Unreal Engine, Crowd Behavior, Evacuation Planning

I. INTRODUCTION

Traditionally, the process of disaster evacuation occurs based on the layout of the floors and the set paths that are created for the best possible situation. However, the Emergency response process, though good, may not work when the situation on the ground is different from what was anticipated. In the case of fires, earthquakes, blasts, and collapses, the exits may become blocked, visibility may decrease, and the manner of movement of people may not follow the anticipated pattern. In such a changing scenario, the traditional method of floor maps may not keep track of the changing environmental conditions, leading to bottlenecks, panic, and hence more casualties.

Traditionally, the process of disaster management has been based on the risk assessment process, which, though good, may not always accurately assess the situation. Therefore, the process of disaster management, based on the traditional method, may not always be precise.

In order to overcome the limitations of the traditional method, this paper proposes an AI-based 3D disaster simulation system, which combines the benefits of AI with the precision of 3D modeling. In the proposed method, the simulation of the disaster situation occurs in real time, and the paths of the people are dynamically updated based on the changing nature of the disaster. In the proposed method, the simulation occurs in 3D, and the conditions such as the spread of fire, the density of smoke, the damage to the structures, and the manner of movement of people are all taken into account.

Unlike the traditional method, the proposed method of disaster management, based on the 3D simulation, uses the AI model, which is more precise and objective. In the proposed method, the simulation occurs in a virtual environment, and the disaster situations are predicted using the AI model. Therefore, the proposed method of disaster management, based on the 3D simulation, can be considered a significant advancement in the contemporary scenario of disaster management and the optimization of the Emergency response process.

II. EXISTING SYSTEM AND LIMITATIONS

Traditionally, disaster response and planning have been heavily reliant on static floor plans and escape routes. This provides an initial foundation for emergency response planning. However, in the face of real-world surprises, this approach fails to deliver. In the event of a fire, earthquake, explosion, or collapse, escape routes may become obstructed, and the environment may become obscured. Moreover, human behavior may become erratic. In this environment of rapidly changing conditions,

static floor maps and escape planning fail to account for changes in the environment.

This results in a bottleneck of people, gridlocks caused by panic, reduced efficiency in evacuating people, and in some cases, loss of life. Furthermore, this traditional method of planning and response relies on manual risk assessment and human judgment. While this information is valuable, it may fail to capture the complexity of the environment and the interplay of risk factors. Therefore, this method of response planning and preparation may fail to deliver the precision and efficiency required in emergency response situations. In this context, this paper proposes an AI-based 3D disaster response and evacuation planning system. This system incorporates artificial intelligence with precision and accuracy in three-dimensional modeling. This system provides real-time response to emergency situations through the simulation of emergency scenarios. In this environment of rapidly changing conditions, this system continually updates and changes the escape routes to accommodate changes in the environment. This system uses smart technologies to calculate the safest escape routes and minimize the risk of bottlenecking and gridlocks.

This method of response planning and preparation differs significantly from the traditional method. In this method, emergency response planning and preparation rely on computer modeling and artificial intelligence. This method incorporates the use of artificial intelligence to provide predictive results and to simulate emergency response scenarios in a controlled environment. This method provides an opportunity for emergency response planners and response teams to test and evaluate various emergency response scenarios and outcomes.

This method provides an opportunity to evaluate and improve emergency response planning and preparation. This method of emergency response planning and preparation provides a marked improvement over the traditional method of response planning and preparation.

III. PROPOSED SYSTEM

The idea behind this proposal is to utilize Unreal Engine to design a digital space that is a 3D model of buildings or other constructions. It is a detailed space that enables one to explore the space and its dimensions in great detail. However, the real magic lies in how one navigates this space, moving up, down, and across in certain ways. This space also enables one to have a detailed analysis of how one navigates this space, especially in the vertical axis, which is often the hardest to perfect in this system.

Key features:

- AI-based autonomous agents that exhibit human-like behavior

- Dynamic hazard triggers such as fire and smoke

- Real-time recalculation of evacuation routes

- Performance metrics such as bottleneck detection and evacuation efficiency

- Scalability and smartness in the management of disasters

IV. METHODOLOGY

They're talking about a system using Unreal Engine for the creation of a digital version of a building or similar structure. It's a 3D setup where you get to explore the space more closely. The key thing, at least from my perspective, is the way movement is handled—up and down, back and forth, etc., with restrictions on those movements. It's a space where you get a thorough examination of all those things, and sometimes the vertical movement is the more difficult thing to get right.

Key Features:

- AI-driven autonomous agents with realistic human behavior.

- Dynamic hazard triggers such as fire and smoke.

- Real-time updates for evacuation routes.

- Performance metrics such as bottleneck detection and evacuation efficiency.

This is a system with a lot of potential for disaster management.

V. HUMAN BEHAVIOR MODELING

A good simulation of a disaster must take into consideration that people behave differently in such situations.

Panic and Congestion: This model considers the density of the crowd and the location of the bottlenecks caused by narrow exits.

Rule-based Motion: Agents move away from danger zones and choose the closest exit using simple rules.

Diversity in the Crowd: Agents move at different speeds and have different reaction times to represent real people.

VI. APPLICATIONS

- The system that is being proposed finds its place in the following areas:
- Public infrastructure, which includes schools, hospitals, and shopping centers.
- Transportation infrastructure, which includes airports and metro stations.
- Smart city systems, which include pairing with IoT-based disaster monitoring systems.

VII. ADVANTAGES AND CHALLENGES

- Objective accuracy, which reduces subjective bias in safety assessment.
- Visual clarity through the use of 3D visualization, which enhances risk assessment.
- Cost efficiency through the use of unlimited virtual drills.
- Robustness through the use of ensemble pathfinding.

VIII. FUTURE SCOPE

- Possible future upgrades:
- Real-time IoT sensor integration.
- Deep learning-based behavioral prediction.
- Cloud-based disaster monitoring systems.
- Large-scale smart city implementations.

IX. SOFTWARE AND TECHNOLOGIES UTILIZED

The AI-based 3D evacuation simulation system, which will be designed for the proposed project, will incorporate the latest tools and technology for developing its various components. This means the use of the latest 3D simulation tools, techniques, and programming/scripting methods for:

- Realistic modeling

- Intelligent decision-making

A. Unreal Engine 5

Unreal Engine 5 will be the simulation environment for the proposed project, which is a fast, powerful, and real-time 3D rendering and simulation engine. It has the following features:

- High-quality rendering with user-friendly features.

- Real-time simulation of geometry and physics for the simulation of objects and buildings.

- Digital Twins of existing architectural structures for precise spatial analysis and simulation of crowds.

- Key features of Unreal Engine 5:
  - NavMesh for navigation.
  - Real-time lighting and physics.
  - Blueprint visual scripting.
  - Dynamic hazard triggering.

B. AI Pathfinding Algorithm

For the simulation, intelligent pathfinding algorithms will be integrated into the Unreal Engine AI system, which will be utilized by the AI agents for intelligent decision-making. The main AI algorithm will be the A* Algorithm, also known as the A-Star Algorithm, which will be utilized for the determination of the shortest and safest path from the current position of the AI agent to the nearest exit during a disaster by evaluating the path that covers the minimum distance. In addition, the Ensemble-Based Decision Logic will be utilized for the evaluation of the various route options, resulting

in a robust output for the AI agent.

C. C++ Programming Support

C++ programming support will be utilized for the development of the project, which will be integrated into the Unreal Engine 5 simulation environment for:

- Developing intelligent behavior for the AI agents.

- Developing real-time hazards.

X. CONCLUSION

The AI-based 3D simulation for evacuation enhances the conventional approach to evacuation. By incorporating intelligent path algorithms, ensemble learning, and hazard modeling, the AI-based 3D simulation for evacuation offers a promising solution for disaster management. In the near future, such systems are likely to become an integral part of the disaster management approach.

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