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MULTI-AGENT Disaster Management System

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Abstract: *Natural disasters continue to create significant challenges for emergency response teams due to delays in incident assessment, inefficient allocation of rescue resources, and lack of coordinated decision making. Conventional disaster management systems mainly depend on manual operations, making it difficult to respond effectively when multiple emergencies occur simultaneously. This paper presents a Multi-Agent Disaster Management Simulator that automates the disaster response process using intelligent software agents, machine learning, graph-based routing, and generative artificial intelligence. The proposed system consists of four autonomous agents responsible for incident detection, resource allocation, rescue coordination, and performance evaluation. A Random Forest model predicts disaster severity using environmental and demographic features, while the A* search algorithm identifies the shortest rescue path between response teams and disaster locations. Google Gemini API is integrated to generate human-readable explanations for resource allocation decisions. A React-based dashboard provides live visualization of incidents, rescue routes, and performance metrics through WebSocket communication. Experimental results demonstrate that the proposed approach improves response efficiency, reduces manual intervention, and provides better transparency during emergency management. The simulator also supports offline execution through rule-based fallbacks, making it suitable for academic research, training, and disaster response simulations.*

Keywords: *Natural disasters*.

1. INTRODUCTION

Natural disasters such as floods, cyclones, earthquakes, landslides, and forest fires affect millions of people every year. During emergency situations, disaster response teams must make quick decisions regarding rescue operations, resource allocation, and evacuation planning. Traditional disaster management systems mainly rely on manual coordination, where operators analyse incoming reports and assign rescue teams based on experience. Such approaches become inefficient when several disasters occur simultaneously because information overload often leads to delayed responses and inconsistent decision making.

Recent developments in Artificial Intelligence and Multi-Agent Systems provide new opportunities to automate emergency management. Multiple software agents can independently perform specialized tasks while communicating with one another to complete an entire rescue operation. Machine learning techniques can estimate disaster severity from environmental conditions, while graph search algorithms can determine the shortest rescue routes. Large Language Models further improve transparency by generating understandable explanations for emergency decisions.

This work proposes a Multi-Agent Disaster Management Simulator that integrates intelligent agents, machine learning, route optimization, and Generative AI into a single web-based platform. The system demonstrates how autonomous software components can collaborate to improve disaster response efficiency while providing real-time visualization and performance monitoring.

A. Statement of the problem

Emergency response organizations continue to face several operational challenges during disaster situations. Incident severity is generally assessed manually, resulting in inconsistent prioritization. Rescue resources are often allocated

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based on limited information, while conventional routing methods fail to consider blocked roads and changing disaster conditions. Existing systems also provide very limited explanation regarding why specific decisions are taken, reducing transparency and post-disaster analysis capabilities. These limitations motivate the development of an intelligent system capable of automating disaster assessment, resource allocation, route planning, and decision explanation.

B. Motivation

The increasing frequency of natural disasters highlights the need for faster and more reliable emergency response systems. Modern Artificial Intelligence techniques provide the capability to automate complex decision-making tasks that traditionally require significant human effort. Developing a multi-agent disaster management platform demonstrates how machine learning, autonomous software agents, and real-time communication can improve rescue operations while reducing human workload. The project also provides an effective educational platform for understanding intelligent coordination systems.

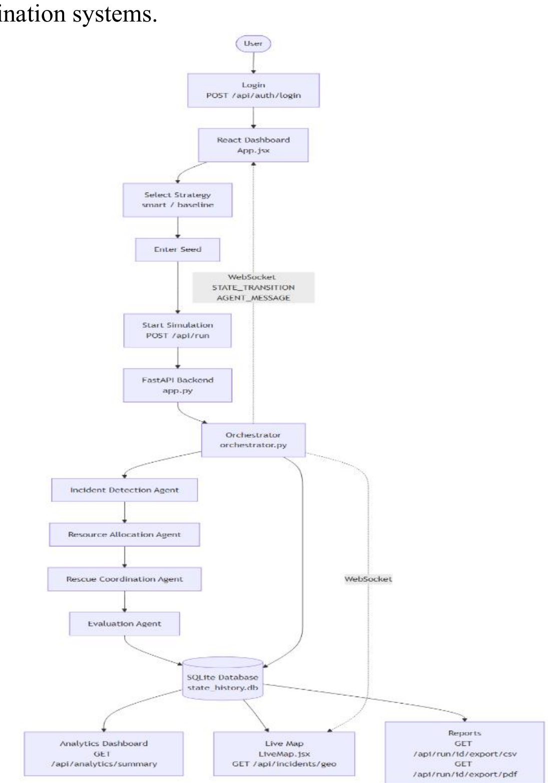

Fig. 1 Overall Workflow

II. RELATED WORK

Several disaster management systems have been developed to improve emergency response and resource coordination. The India Disaster Resource Network (IDRN) provides a centralized database containing information about disaster response resources such as rescue teams, vehicles, medical facilities, and emergency equipment. Although it assists authorities in locating available resources, it does not perform automatic severity assessment or intelligent resource allocation.

Sahana Eden is an open-source disaster management platform widely used for volunteer management, shelter coordination, inventory tracking, and information sharing. While it supports disaster response activities effectively,

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decision making still depends largely on human operators, and the system lacks predictive intelligence for prioritizing incidents.

The Global Disaster Alert and Coordination System (GDACS) focuses on monitoring natural disasters using satellite observations and meteorological information. It provides early warnings but does not coordinate rescue operations or optimize rescue routes.

Several academic studies have explored multi-agent disaster response systems where autonomous software agents cooperate to solve emergency management problems. These studies demonstrate the benefits of distributed intelligence; however, many remain simulation-oriented and do not integrate machine learning, route optimization, real-time dashboards, and explainable artificial intelligence into a single platform.

Feature	IDRN	Sahana Eden	GDACS	Proposed System
Machine Learning Prediction	No	No	No	Yes
Multi-Agent Coordination	No	Partial	No	Yes
Route Optimization	No	No	No	Yes
AI Decision Explanation	No	No	No	Yes
Real-Time Dashboard	Limited	Yes	Yes	Yes
Report Generation	Basic	Partial	No	Yes

B. Research Gap

The survey of existing disaster management solutions reveals several important limitations. Most systems continue to depend on manual evaluation of disaster reports, leading to inconsistent severity assessment during large-scale emergencies. Existing platforms rarely incorporate machine learning techniques to predict disaster severity automatically using environmental and demographic information.

Another major limitation is the absence of intelligent rescue route planning. Conventional mapping systems calculate the shortest distance but cannot simulate disaster-specific conditions such as blocked roads or damaged infrastructure. Consequently, rescue teams may experience unnecessary delays while reaching affected locations.

Furthermore, existing disaster response applications provide limited support for explaining why specific rescue teams or resources are selected. The lack of transparent decision-making makes post-disaster analysis difficult. These limitations indicate the need for a unified disaster management platform that combines autonomous agents, predictive analytics, optimized routing, and explainable artificial intelligence.

III. PROPOSED SYSTEM

The proposed Multi-Agent Disaster Management Simulator provides an intelligent framework for coordinating disaster response activities through autonomous software agents. The system combines machine learning, graph-based routing, real-time communication, and generative artificial intelligence within a web-based application.

The simulator consists of four specialized agents. The Incident Detection Agent analyses disaster information and predicts severity using a trained Random Forest classifier. The Resource Allocation Agent identifies available rescue teams and determines the most suitable deployment strategy. The Rescue Coordination Agent computes the optimal rescue path using the A* search algorithm and monitors rescue progress. Finally, the Evaluation Agent analyses overall system performance and generates detailed reports.

A FastAPI backend manages communication among agents through a centralized message bus, while a React dashboard provides real-time visualization of incidents, rescue routes, system metrics, and simulation statistics. Google Gemini API generates human-readable explanations describing severity analysis, resource allocation decisions, evacuation recommendations, and emergency response strategies.

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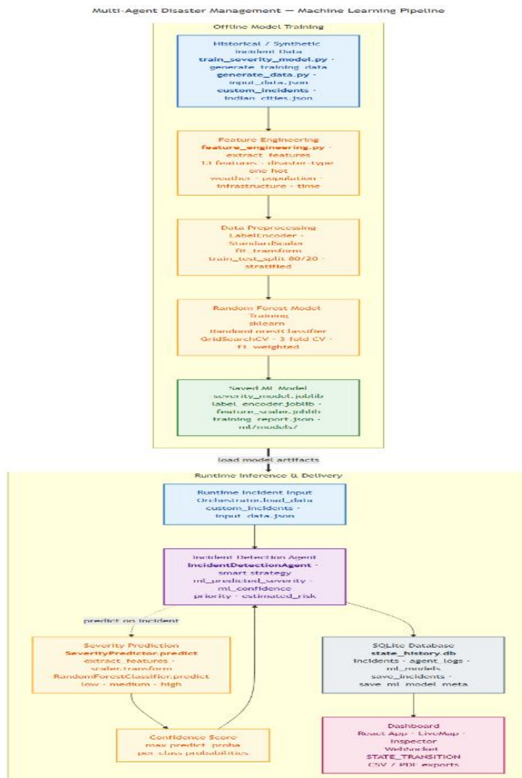

Fig.2 Multi Agent System Workflow

B. Objectives

The primary objectives of the proposed system are as follows:

Develop an intelligent disaster management simulator capable of coordinating multiple rescue operations.

Predict disaster severity using a Random Forest machine learning model.

Allocate rescue resources automatically based on predicted disaster priority.

Compute optimal rescue routes using the A* pathfinding algorithm.

Generate explainable disaster response recommendations using Generative AI.

Provide a real-time web dashboard for monitoring disaster simulations.

Store simulation history and performance metrics for evaluation and future analysis.

IV. SYSTEM ARCHITECTURE PROPOSED

The proposed architecture follows a modular design consisting of four major layers. The Presentation Layer contains the React dashboard through which users initiate simulations and monitor rescue operations. The Application Layer is implemented using Fast API and handles API requests, user authentication, and communication between software agents.

The Service Layer contains four autonomous agents responsible for disaster detection, resource allocation, rescue coordination, and performance evaluation. These agents exchange messages through a centralized communication bus, allowing independent execution while maintaining coordinated workflow.

The Data Layer consists of an SQLite database that stores user information, disaster incidents, simulation logs, rescue team details, and evaluation metrics. Machine learning models and configuration files are also maintained within this layer to support prediction and analysis.

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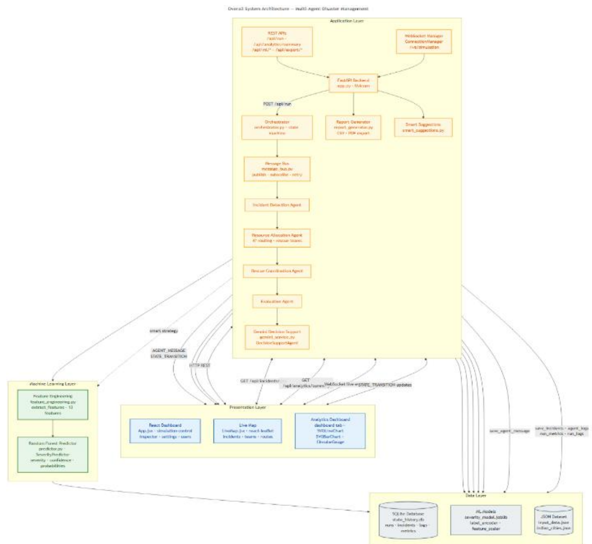

Fig. 3. Three tier system architecture

V. EXISTING SYSTEMS AND LIMITATIONS

Current disaster management systems provide valuable support for maintaining disaster-related information and coordinating emergency resources. However, they are associated with several limitations that reduce their effectiveness during large-scale emergency situations.

Most existing systems rely on manual assessment of disaster severity, resulting in inconsistent prioritization of incidents. Resource allocation is generally performed by human operators, which increases response time during multiple simultaneous emergencies. Conventional routing methods calculate only the shortest geographical distance without considering disaster-specific constraints such as damaged roads or blocked transportation routes.

Another significant limitation is the absence of intelligent decision explanation. Existing applications generally display rescue information without explaining why a particular rescue team or allocation strategy has been selected. Furthermore, many platforms do not provide integrated machine learning models capable of predicting disaster severity using environmental and demographic information.

VI. PROPOSED METHODOLOGY

The proposed disaster management simulator follows a sequential multi-agent workflow in which each software agent performs a specific task while communicating through a centralized message bus. The modular design improves scalability, reduces processing complexity, and allows each component to operate independently.

Initially, the user starts a disaster simulation through the React-based dashboard by selecting the simulation parameters. The disaster information is forwarded to the FastAPI backend, where the Incident Detection Agent receives the incident details.

The Incident Detection Agent analyzes environmental and demographic attributes such as disaster type, rainfall, wind speed, temperature, humidity, infrastructure condition, and affected population. These features are processed using a trained Random Forest classifier to estimate the disaster severity. The predicted severity level is then forwarded to the Resource Allocation Agent.

The Resource Allocation Agent identifies available rescue teams from the database and determines the most suitable response unit. The A* search algorithm computes the shortest rescue route by considering the geographical locations of rescue teams and disaster sites. The optimized path is then transmitted to the Rescue Coordination Agent.

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The Rescue Coordination Agent simulates rescue operations by assigning emergency personnel and estimating the number of lives that can be saved based on available resources. Finally, the Evaluation Agent analyzes the overall performance of the simulation by calculating rescue efficiency, response time, and resource utilization. Google Gemini API generates detailed explanations describing the allocation strategy and recommended emergency actions.

The simulation results are displayed on the dashboard through WebSocket communication, allowing users to monitor disaster events, rescue progress, and system performance in real time.

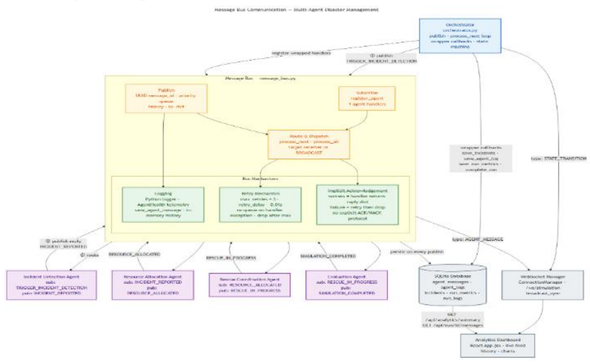

Fig. 4. Workflow of the Proposed Multi-Agent Disaster Management System

VII. MACHINE LEARNING MODEL

Machine learning plays a significant role in predicting disaster severity before rescue operations begin. A Random Forest classifier is trained using a synthetic disaster dataset containing environmental, geographical, and demographic information.

The dataset includes several important features such as disaster category, number of affected people, rainfall, temperature, humidity, wind speed, infrastructure condition, and population density. Feature engineering techniques are applied before training the classification model to improve prediction accuracy.

During simulation, incoming disaster reports are processed using the trained model, which classifies each incident into predefined severity categories. These predictions enable the system to prioritize emergency response activities automatically.

The trained model demonstrated reliable classification performance and successfully supported intelligent resource allocation throughout the simulation process.

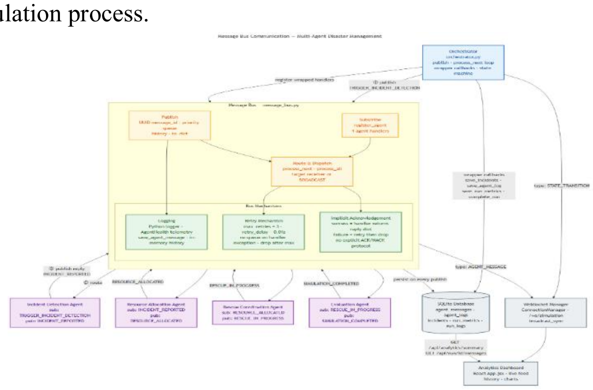

Figure 4. Machine Learning Prediction Pipeline

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VIII. RESULTS AND DISCUSSION

The developed simulator successfully demonstrated coordinated disaster response using autonomous software agents. The web dashboard displayed live disaster incidents, optimized rescue routes, rescue team locations, and simulation statistics in real time.

The Random Forest model accurately classified disaster severity based on environmental parameters, allowing rescue teams to prioritize high-risk incidents efficiently. The A* pathfinding algorithm consistently generated shorter rescue routes, reducing estimated response time during simulation.

Integration of Google Gemini API improved system transparency by generating understandable explanations for disaster severity assessment, resource allocation, evacuation planning, and recommended emergency actions. These explanations provide valuable support for decision-makers during emergency management.

The real-time dashboard enabled continuous monitoring of system performance through live charts, geographical visualization, and rescue metrics. Experimental evaluation indicated improved coordination among software agents and reduced dependence on manual decision-making compared with conventional disaster management approaches.

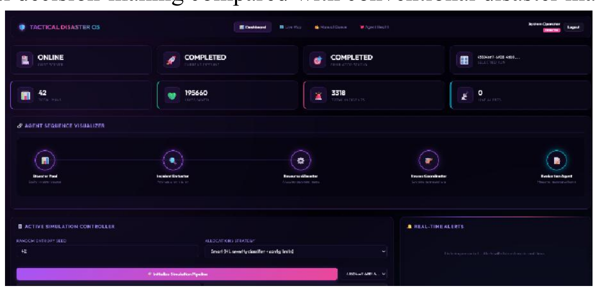

Figure 5. Dashboard Showing Disaster Simulation

Figure 6. Live Rescue Route Visualization

Parameter	Result
Machine Learning Model	Random Forest
Severity Prediction	Automated
Route Optimization	A* Algorithm
AI Decision Support	Google Gemini API
Dashboard	React + Fast API
Communication	WebSocket
Database	SQLite
Rescue Coordination	Multi-Agent System

IX. CONCLUSION

This paper presented a Multi-Agent Disaster Management Simulator that integrates machine learning, autonomous software agents, route optimization, and Generative AI into a unified disaster response platform. The proposed system automates disaster severity prediction, rescue team allocation, shortest route computation, and performance evaluation while providing real-time visualization through an interactive web dashboard.

The Random Forest classifier enabled accurate disaster severity prediction, whereas the A* search algorithm improved rescue route planning. Integration of Google Gemini API enhanced decision transparency by producing understandable emergency response recommendations. The modular multi-agent architecture demonstrated efficient coordination among different disaster management activities.

Overall, the proposed system provides a scalable and intelligent platform suitable for disaster response simulation, emergency management research, and educational applications.

X. FUTURE SCOPE

The proposed system can be further enhanced by integrating real-time weather services, satellite imagery, drone surveillance, and IoT sensor networks to improve disaster detection accuracy. Future work may also incorporate deep learning models for more accurate disaster prediction, reinforcement learning for adaptive resource allocation, and cloud-based deployment to support large-scale emergency operations across multiple geographical regions.

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