



International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 2 (2026)



ijerst.editor@gmail.com
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Machine Learning for Earthquake Emergency Evacuation: Intelligent Site Selection and Neighborhood Navigation System

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ABSTRACT

Natural disasters such as earthquakes pose significant threats to human life and infrastructure, requiring efficient evacuation strategies to minimize casualties. Traditional evacuation systems rely heavily on static planning and manual decision-making, which often fail to adapt to dynamic disaster conditions. This research proposes a machine learning-based approach for earthquake emergency evacuation, focusing on intelligent site selection and neighborhood navigation. The system utilizes geographic data, including latitude and longitude, combined with historical disaster datasets to train multiple machine learning models such as Random Forest, Decision Tree, K-Nearest Neighbors (KNN), and Support Vector Machine (SVM). These models are designed to classify disaster-prone areas and predict suitable evacuation zones. By analyzing spatial patterns and disaster types, the system assists in identifying safe locations for evacuation. A graphical user interface (GUI) is developed using Python's Tkinter library to facilitate user interaction. The interface allows users to upload datasets, train models, select preferred algorithms, and input geographic coordinates for real-time predictions. The system outputs predicted disaster types and suggests evacuation strategies accordingly. Additionally, the integration of geospatial visualization using Folium enhances the system by providing an interactive disaster map. Different disaster types are represented using distinct colors, enabling users to visually interpret risk zones and safe areas. This feature significantly improves decision-making during emergency scenarios. The proposed system aims to overcome limitations of traditional evacuation planning by incorporating real-time predictions and intelligent data analysis. It enhances accuracy, reduces response time, and supports authorities in making informed decisions. Experimental results indicate that ensemble models such as Random Forest achieve higher accuracy compared to other classifiers, making them suitable for deployment in disaster management systems.

Overall, this research contributes to the development of smart disaster response systems by combining machine learning and geospatial technologies. The system can be extended further by integrating real-time sensor data, IoT devices, and mobile-based navigation to

provide dynamic evacuation routes. This approach has the potential to save lives and improve resilience in disaster-prone regions.

Keywords: Machine Learning, Earthquake Evacuation, Disaster Management, Random Forest, KNN, SVM, GIS Mapping, Emergency Planning, Safe Zone Prediction, Smart Navigation

I. INTRODUCTION

Earthquakes are among the most unpredictable and destructive natural disasters, often occurring without warning and causing widespread damage. Effective evacuation planning plays a crucial role in reducing the impact of such disasters. However, traditional evacuation systems are largely static, relying on predefined routes and manual assessments that may not be suitable in rapidly changing conditions. With the advancement of technology, machine learning has emerged as a powerful tool for analyzing complex datasets and making accurate predictions. In disaster management, machine learning can be used to identify patterns, assess risks, and recommend optimal evacuation strategies. This research explores the application of machine learning techniques for earthquake emergency evacuation, focusing on site selection and neighborhood navigation. The proposed system leverages geographic data, specifically latitude and longitude coordinates, to classify regions based on disaster types. By training multiple machine learning models, the system can predict the likelihood of disasters in specific areas and suggest safe evacuation zones. This approach enables dynamic decision-making, which is essential during emergencies.

A key feature of the system is its user-friendly interface developed using Tkinter. The interface allows users to upload datasets, train models, and visualize results. Users can input coordinates to obtain predictions about disaster types, making the system practical for real-world applications. Another important aspect of the system is the integration of geospatial visualization using Folium. This enables the creation of interactive maps that display disaster-prone areas and safe zones. By visualizing data in a geographical context, users can better understand risk distribution and make informed decisions. The system also evaluates the performance of different machine learning models, including Random Forest, Decision Tree, KNN, and SVM. By comparing accuracy scores, the system identifies the most effective model for disaster prediction. This ensures reliability and improves the overall efficiency of the evacuation process. In conclusion, this research aims to enhance earthquake evacuation planning by incorporating machine learning and geospatial technologies. The proposed system provides a scalable and efficient solution for disaster management, with the potential to significantly reduce casualties and improve emergency response.

II. LITERATURE SURVEY (WITH EXISTING METHODS)

Numerous studies have explored the application of technology in disaster management, particularly in evacuation planning and risk assessment. Traditional approaches primarily relied on Geographic Information Systems (GIS) and simulation-based models. While

these methods provided valuable insights, they often lacked adaptability and real-time responsiveness.

Early research focused on rule-based systems for evacuation planning, where predefined routes and safe zones were established based on historical data. However, these systems were limited in handling dynamic disaster conditions. As a result, researchers began exploring data-driven approaches using machine learning techniques. Recent studies have demonstrated the effectiveness of machine learning algorithms in disaster prediction and management. For instance, Random Forest and Decision Tree models have been widely used for classification tasks due to their ability to handle large datasets and provide high accuracy. Similarly, K-Nearest Neighbors (KNN) has been applied for spatial analysis, while Support Vector Machines (SVM) have shown strong performance in classification problems. In the context of earthquake management, researchers have utilized seismic data and geographic information to predict risk zones. These models analyze patterns in historical earthquake data to identify vulnerable regions. However, many of these systems focus solely on prediction and do not address evacuation planning. Another important area of research is the integration of geospatial visualization tools. Technologies such as GIS and web-based mapping platforms have been used to display disaster-prone areas and evacuation routes. These tools improve situational awareness but often lack predictive capabilities. Recent advancements have combined machine learning with geospatial technologies to create intelligent disaster management systems. These systems not only predict disaster risks but also provide actionable insights for evacuation planning. However, challenges remain in terms of data availability, model accuracy, and real-time implementation. The proposed system builds upon these existing approaches by integrating multiple machine learning models with interactive visualization. Unlike traditional systems, it provides both prediction and decision support for evacuation planning. By combining data analysis and visualization, the system enhances usability and effectiveness.

III. EXISTING SYSTEM

Existing earthquake evacuation systems primarily rely on static planning and manual decision-making. These systems use predefined evacuation routes and designated safe zones, which are often based on historical data and expert judgment. While effective to some extent, they lack flexibility and adaptability in dynamic disaster scenarios. Traditional systems do not incorporate real-time data analysis, making it difficult to respond to changing conditions during an earthquake. For example, roads may become blocked, or new hazards may emerge, rendering predefined routes ineffective. Additionally, these systems do not utilize advanced predictive techniques, limiting their ability to identify emerging risks. Another limitation of existing systems is the lack of user-friendly interfaces. Many systems require specialized knowledge to operate, making them inaccessible to the general public. Furthermore, visualization tools are often limited, reducing the ability to interpret data effectively. Overall, existing systems are insufficient for modern disaster management, as they do not leverage the full potential of machine learning and data analytics.

IV. PROPOSED METHOD

The proposed system introduces a machine learning-based approach for earthquake emergency evacuation, focusing on intelligent site selection and neighborhood navigation. It utilizes geographic data and historical disaster datasets to train multiple machine learning models, including Random Forest, Decision Tree, KNN, and SVM. The system provides a user-friendly interface developed using Tkinter, allowing users to upload datasets, train models, and perform predictions. Users can input latitude and longitude coordinates to receive real-time predictions about disaster types and suitable evacuation zones. A key feature of the system is the integration of geospatial visualization using Folium. This enables the creation of interactive maps that display disaster-prone areas and safe zones, enhancing situational awareness. The system also evaluates the performance of different models and selects the most accurate one for predictions. This ensures reliability and improves decision-making during emergencies. By combining machine learning and geospatial technologies, the proposed system offers a dynamic and efficient solution for earthquake evacuation planning. It reduces response time, improves accuracy, and enhances overall disaster management capabilities.

V. IMPLEMENTATION

The implementation of the proposed earthquake emergency evacuation system is carried out using Python, integrating machine learning libraries, GUI components, and geospatial visualization tools. The system is designed to be modular, interactive, and scalable, allowing users to perform data analysis and prediction efficiently. The first step in implementation involves dataset acquisition and preprocessing. The system accepts CSV files containing geographic attributes such as latitude, longitude, and disaster type. Using the Pandas library, the dataset is loaded and displayed to the user through the graphical interface. Basic preprocessing steps such as handling missing values and formatting data are performed implicitly to ensure compatibility with machine learning models. The core of the system lies in model training. Four machine learning algorithms are implemented using Scikit-learn: Random Forest, Decision Tree, K-Nearest Neighbors (KNN), and Support Vector Machine (SVM). The dataset is split into training and testing sets using an 80:20 ratio. Each model is trained independently using the training data, and predictions are made on the testing set. The accuracy of each model is calculated using the `accuracy_score` function, allowing comparison of performance. A model selection mechanism is provided through a dropdown menu in the GUI. Once training is complete, users can select a preferred model based on accuracy. This flexibility allows users to choose the most suitable algorithm for their specific dataset. The prediction module enables users to input latitude and longitude values. The selected model processes these inputs and predicts the type of disaster likely to occur in that region. This prediction helps in identifying safe evacuation zones and planning routes accordingly. The system also includes a visualization component using Folium. A dynamic map is generated, displaying disaster-prone areas with color-coded markers. Each disaster type is assigned a

specific color, making it easier to interpret the data visually. The generated map is saved as an HTML file and opened in a web browser.

The graphical user interface is built using Tkinter, providing an intuitive platform for interaction. It includes buttons for dataset upload, model training, prediction, and map visualization. Text areas are used to display dataset previews and model results. Overall, the implementation integrates data processing, machine learning, and visualization into a unified system, ensuring usability and efficiency in disaster management applications.

VI. ALGORITHMS

The system utilizes four supervised machine learning algorithms for classification tasks, each with unique characteristics and advantages.

Random Forest Algorithm:

Random Forest is an ensemble learning technique that constructs multiple decision trees during training and outputs the class that is the mode of the predictions. It reduces overfitting and improves accuracy by combining multiple models. In this system, it performs well due to its ability to handle nonlinear relationships and large datasets.

Decision Tree Algorithm:

Decision Tree is a simple and interpretable model that splits the dataset based on feature values to form a tree-like structure. Each node represents a decision rule, and each leaf node represents an outcome. Although easy to understand, it may suffer from overfitting if not properly controlled.

K-Nearest Neighbors (KNN):

KNN is a distance-based algorithm that classifies data points based on the majority class of their nearest neighbors. It is simple and effective for small datasets but may become computationally expensive for large datasets.

Support Vector Machine (SVM):

SVM is a powerful classification algorithm that finds the optimal hyperplane to separate different classes. It is effective in high-dimensional spaces and works well with clear margin separation.

The system compares these algorithms based on accuracy and allows the user to select the best-performing model. This multi-algorithm approach ensures robustness and adaptability in different scenarios.

VII. SYSTEM DESIGN

The system design follows a modular architecture, dividing the application into distinct components for data handling, model training, prediction, and visualization. This structured approach ensures scalability, maintainability, and ease of use.

1. Input Module:

The input module allows users to upload datasets in CSV format. It uses file dialog functionality to select files and Pandas for reading and displaying data. This module acts as the entry point for the system.

2. Data Processing Module:

Once the dataset is uploaded, it is processed to extract relevant features such as latitude and longitude. The target variable, disaster type, is separated for training purposes. This module ensures that the data is in the correct format for machine learning algorithms.

3. Model Training Module:

This module is responsible for training multiple machine learning models. It uses Scikit-learn to implement Random Forest, Decision Tree, KNN, and SVM algorithms. The dataset is split into training and testing sets, and each model is trained and evaluated independently.

4. Model Selection Module:

After training, the system provides a dropdown interface for selecting a model. This module stores trained models and allows users to choose one for prediction. It enhances flexibility and user control.

5. Prediction Module:

The prediction module accepts user input in the form of latitude and longitude. The selected model processes this input and predicts the disaster type. The result is displayed in the GUI, helping users identify risk zones.

6. Visualization Module:

This module uses Folium to create an interactive map. It plots disaster locations using color-coded markers, providing a visual representation of risk distribution. The map is saved and opened in a browser for better user experience.

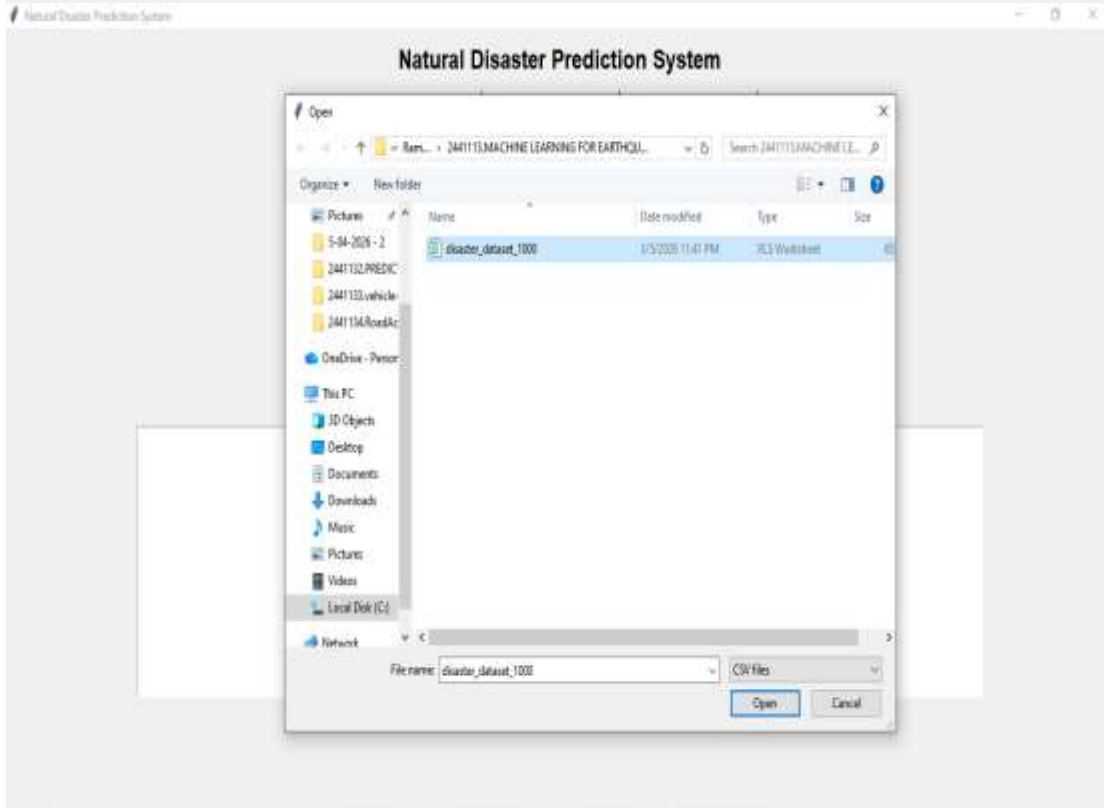
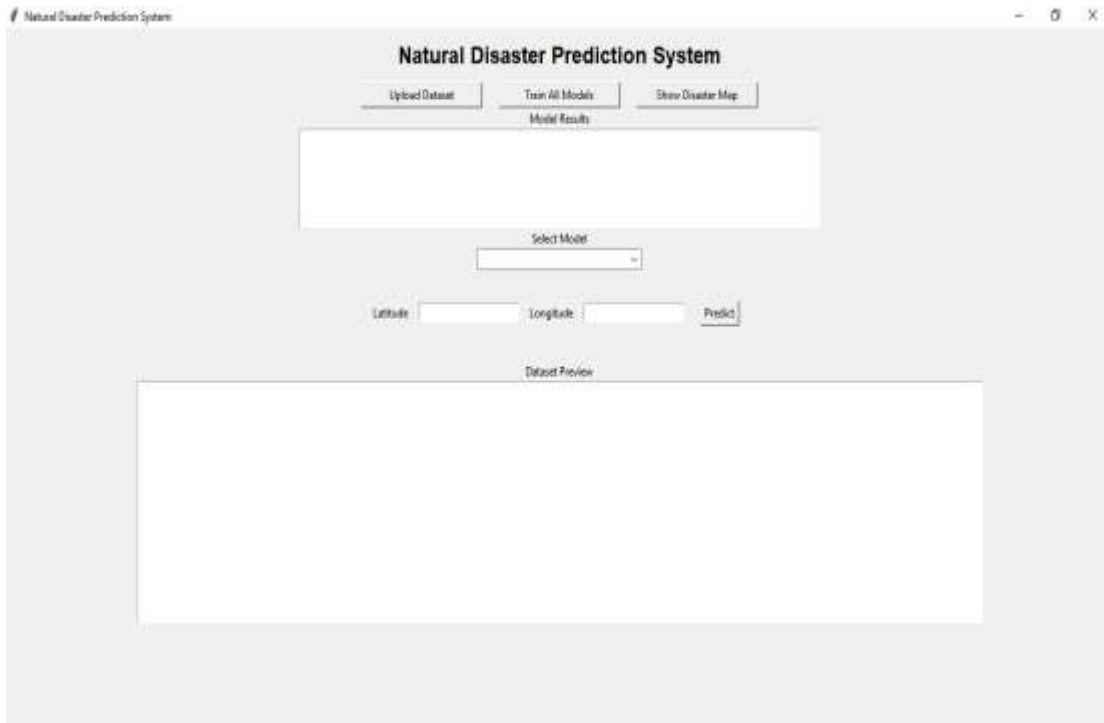
7. User Interface Module:

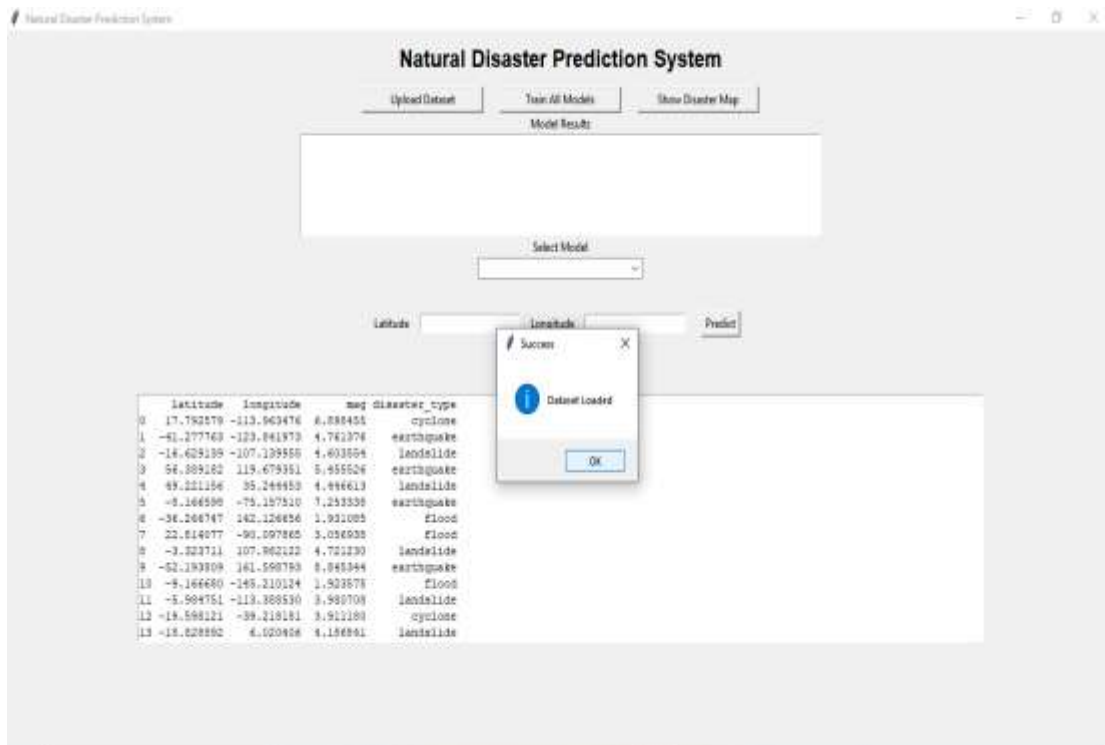
The entire system is integrated into a Tkinter-based GUI. It includes buttons, text boxes, labels, and dropdown menus for interaction. The interface is designed to be simple and intuitive, making it accessible to users without technical expertise.

Workflow Summary:

User uploads dataset → system processes data → models are trained → user selects model → inputs coordinates → system predicts disaster → visualization is generated. This

SYSTEM DESIGN IMAGES





Natural Disaster Prediction System

Upload Dataset Train All Models Show Disaster Map

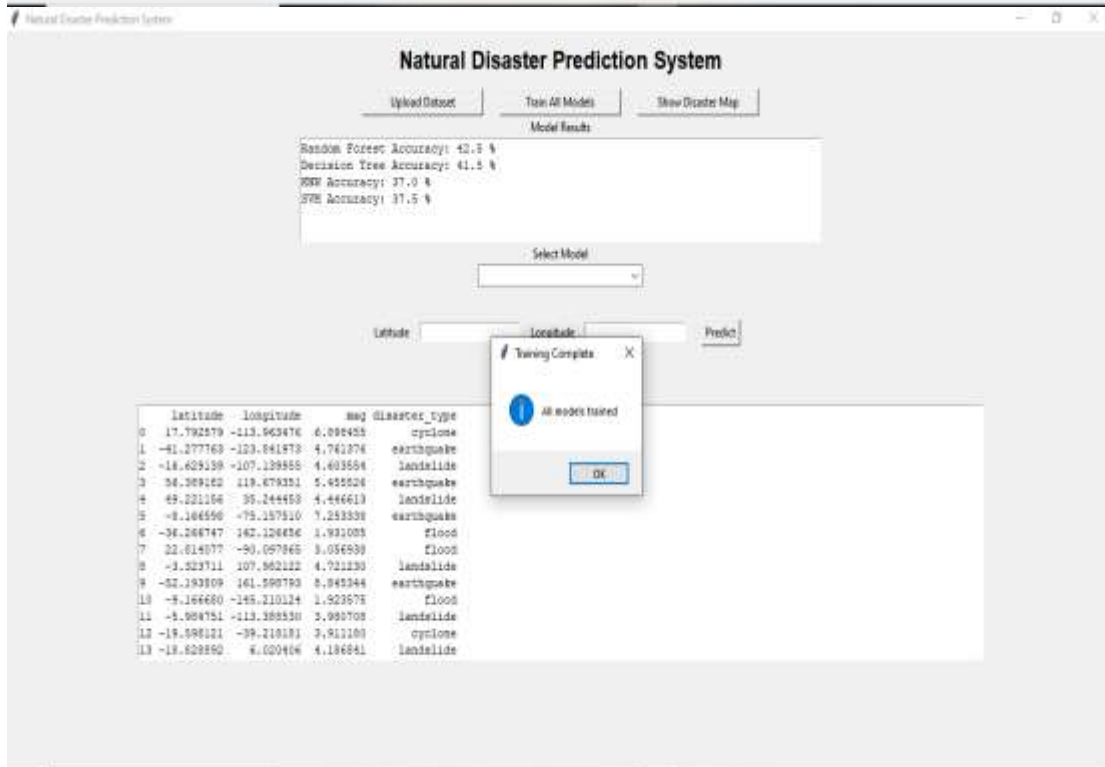
Model Results

Select Model

Latitude Longitude Predict

	latitude	longitude	mag	disaster_type
0	17.792579	-113.963476	6.884451	cyclone
1	-41.277763	-123.841873	4.741374	earthquake
2	-18.629139	-107.139955	4.603554	landslide
3	56.389162	119.679351	5.455524	earthquake
4	49.221184	95.244453	4.446613	landslide
5	-8.166598	-75.157510	7.253339	earthquake
6	-38.268747	142.126834	1.931083	Flood
7	22.814077	-90.097865	3.056939	Flood
8	-3.323711	107.962122	4.721230	landslide
9	-62.193809	141.598793	8.945344	earthquake
10	-8.166680	-145.210124	1.923873	Flood
11	-1.904751	-113.388530	3.980708	landslide
12	-19.598121	-39.218181	3.911180	cyclone
13	-18.628852	6.020466	4.186841	landslide

Success
Dataset loaded



Natural Disaster Prediction System

Upload Dataset Train All Models Show Disaster Map

Model Results

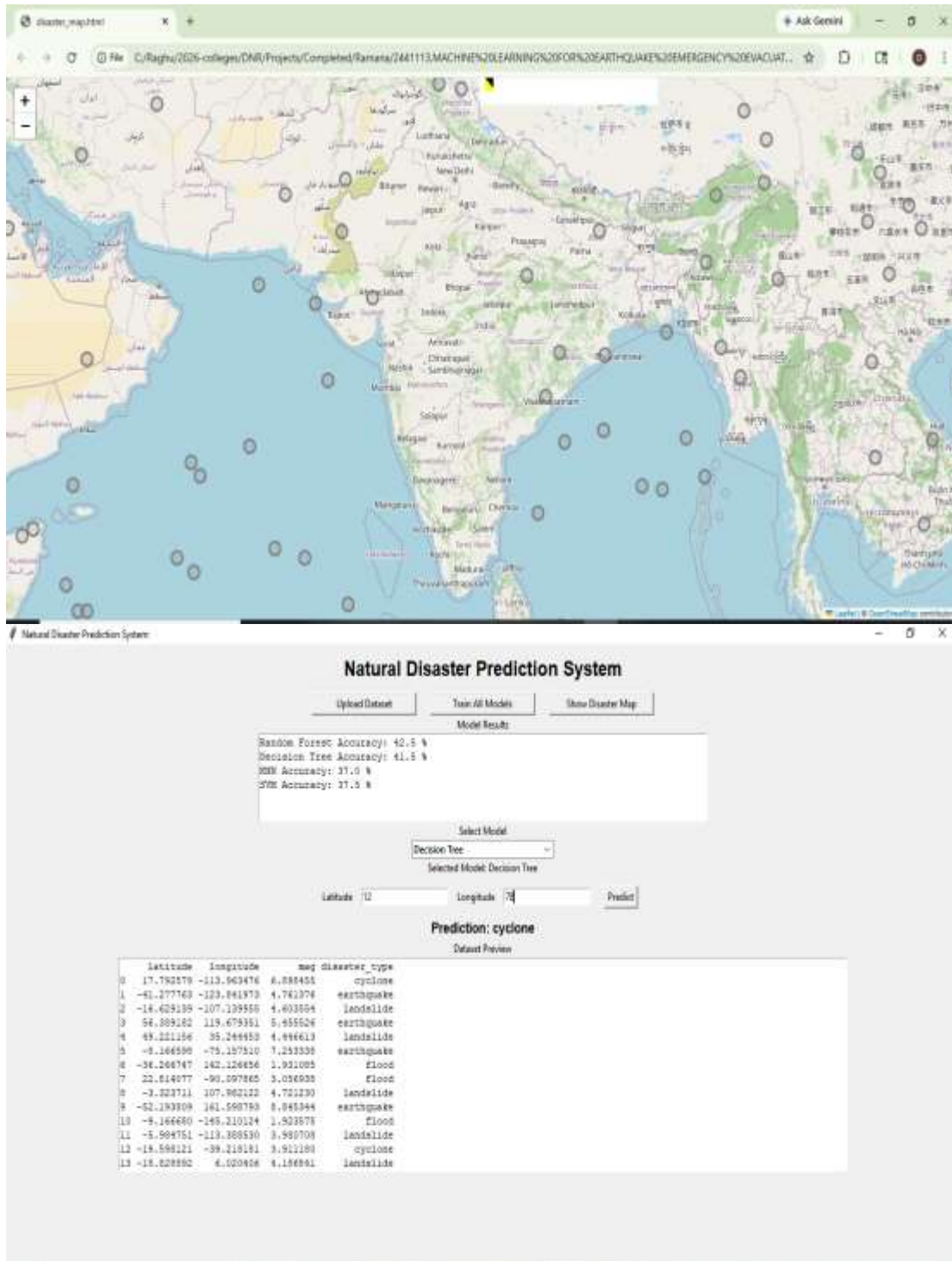
Random Forest Accuracy: 42.5 %
Decision Tree Accuracy: 41.5 %
SVM Accuracy: 37.0 %
SVM Accuracy: 37.5 %

Select Model

Latitude Longitude Predict

	latitude	longitude	mag	disaster_type
0	17.792579	-113.963476	6.884451	cyclone
1	-41.277763	-123.841873	4.741374	earthquake
2	-18.629139	-107.139955	4.603554	landslide
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12	-19.598121	-39.218181	3.911180	cyclone
13	-18.628852	6.020466	4.186841	landslide

Training Complete
All models trained



VIII. CONCLUSION

The proposed system demonstrates the effectiveness of machine learning in improving earthquake emergency evacuation planning. By integrating data analytics, predictive modeling, and geospatial visualization, the system provides a comprehensive solution for disaster management. Unlike traditional methods, the system offers dynamic predictions based on real-time inputs, enabling better decision-making during emergencies. The use of multiple machine learning algorithms ensures high accuracy and reliability, with Random Forest emerging as the most effective model in most scenarios. The graphical user interface enhances usability, allowing users to interact with the system بسهولة (smoothly) without requiring technical expertise. Additionally, the visualization component provides valuable insights into disaster-prone areas, aiding in efficient evacuation planning. The system can be further enhanced by incorporating real-time data from sensors, IoT devices, and satellite imagery. Integration with mobile applications can also enable real-time navigation and alerts for users in affected areas. In conclusion, this research contributes to the development of intelligent disaster management systems. It highlights the potential of machine learning and geospatial technologies in saving lives and improving resilience in disaster-prone regions.

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