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AI-Powered Weather System with Disaster Prediction

Cedric Ngendahimana and Ms. Fanny Chatola
Department of Computer Science
DMI-St. John the Baptist University, Lilongwe, Malawi
cypscedricjr@gmail.com

Abstract*:* *This project develops an AI-powered weather system that aims to improve disaster prediction and preparedness through advanced machine learning algorithms and real-time meteorological data. By collecting data from the OpenWeatherMap API, the system analyzes key environmental indicators, including rainfall, temperature, and wind speed, to detect risks of floods, droughts, cyclones, hailstorms, and wildfires. Through machine learning models like linear regression and threshold-based heuristics, the system achieves high predictive accuracy for natural disasters.*

This study demonstrates the effectiveness of AI in early warning systems, thus enhancing community preparedness and supporting timely interventions by authorities.

The threshold-based heuristics method involved setting predetermined weather condition limits based on historical disaster data, where surpassing these thresholds indicates high disaster risk. Linear regression was used to forecast variables like rainfall and temperature, essential for early warning in disaster management. Both techniques were implemented in tandem, with linear regression providing probabilistic outputs that feed into the heuristic system to improve prediction accuracy

Keywords: AI (Artificial Intelligence), Weather Prediction, Natural Disaster Alerts, ML (Machine Learning), Disaster Preparedness, GIS (Geographic Information System), API (Application Programming Interface)

I. INTRODUCTION

Natural disasters such as floods, droughts, and cyclones cause severe harm to human life, infrastructure, and economies. As climate change increases the frequency and intensity of these events, effective disaster prediction systems become critical. Traditional methods often lack the precision needed for accurate forecasts, but recent advancements in artificial intelligence (AI) and machine learning (ML) offer a promising solution. This project presents an AI-powered system that predicts weather-related disasters by analyzing real-time data from the OpenWeatherMap API. Using techniques like linear regression and threshold-based heuristics, the system monitors key indicators rainfall, temperature, and wind speed to deliver timely warnings. By enhancing accuracy in disaster forecasting, this system supports early interventions, aiming to improve community resilience and inform decisions for public safety.

Recent studies demonstrate the impactful role of machine learning in climate prediction, yet each presents unique limitations. Vasantha (2019) introduced a model for forecasting heavy rainfall, useful for early warning systems but reliant on extensive data. Davenport and Diffenbaugh (2021) analyzed pollution-related factors in Midwest precipitation, though isolating these factors is complex. Ma and Zhai (2019) developed a dual-step wind energy prediction model, accurate but computationally intensive. Du et al. (2021) used Bayesian neural networks to predict failure risks in power systems, enhancing resilience but susceptible to overfitting with limited data. Huang et al. (2021) applied machine learning to solar radiation forecasting, informing climate event preparation, though variability in solar conditions can impact accuracy. These studies collectively highlight machine learning's potential and challenges in advancing climate science.

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II. LITERATURE REVIEW

Recent studies highlight the diverse applications of machine learning in climate science, showcasing both advantages and limitations. In 2019, **B. Vasantha** developed a model for heavy rainfall prediction using global climate parameters, valuable for anticipating extreme events but limited by its reliance on extensive historical data. **F.V. Davenport and N.S. Diffenbaugh** (2021) examined the role of pollution in U.S. Midwest extreme precipitation, aiding climate change understanding, though isolating causative factors remains complex. **Yuan-Jia Ma and Ming-Yue Zhai** (2019) introduced a dual-step model for wind energy prediction, enhancing renewable forecasts but demanding high computational resources. **Y. Du, Y. Liu, X. Wang, J. Fang, G. Sheng, and X. Jiang** (2021) used Bayesian neural networks to assess weather-related failure risks in distribution systems, improving resilience but potentially overfitting with limited data. **Huang, L.; Kang, J.; Wan, M.; Fang, L.; Zhang, C.; and Zeng, Z.** (2021) applied machine learning to solar radiation prediction, supporting climate event preparation, though variability in solar conditions challenges accuracy. Collectively, these studies advance climate science, despite challenges in balancing accuracy, data availability, and computational demands.

Assumption

The system operates under several key conditions. It relies on the availability of accurate, real-time weather data from the OpenWeatherMap API, ensuring that necessary parameters such as temperature, rainfall, and wind speed are included in the response. The threshold-based heuristics are based on predefined limits for predicting natural disasters, such as rainfall for floods or wind speed for cyclones, which are assumed to be valid for the target geographical area but may require adjustments for different locations. The linear regression model used for disaster prediction is considered reliable, drawing on historical data that reflects future weather patterns. Users are expected to provide accurate location data, and the system assumes that the 16-day weather forecast from the API is sufficiently reliable, despite potential inaccuracies in longer-term forecasts. Additionally, the system presumes that its hardware and software configurations, including server specifications and database setups, are capable of handling the necessary data retrieval, processing, and analysis without performance issues. These conditions define the system's operational context and its limitations.

III. METHODOLOGY

The weather forecasting system offers several advantages, including its ability to provide accurate and real-time weather data for up to 16 days, enhancing preparedness for potential natural disasters. By leveraging the OpenWeatherMap API, the system offers global coverage, allowing users to forecast weather conditions for any city. The integration of predefined disaster risk thresholds (e.g., heavy rainfall for floods, high temperatures for droughts) provides proactive alerts, helping communities prepare for extreme weather events. Additionally, the use of Python libraries like matplotlib enables clear and effective data visualization, making it easier for users to interpret forecast trends. The system's flexibility allows for future integration with databases like MySQL or MongoDB for more robust data storage and analysis. Moreover, the modular structure and reproducibility ensure the system can be easily adapted and scaled to meet specific user needs, ensuring reliability and accessibility

The development follows Agile methodology, enabling iterative enhancement and flexible response to user feedback. Each module, from data collection to user notifications, was designed and tested individually to ensure functionality. The system architecture comprises real-time data acquisition, processing, analysis, and alert mechanisms. A detailed breakdown includes the Data Preprocessing Module for data cleaning, the Authentication Module for secure access, and the Database Management for storing historical weather and disaster data. Design diagrams, such as a system architecture diagram and a data flow diagram, demonstrate the flow of data from input through analysis and alert output.

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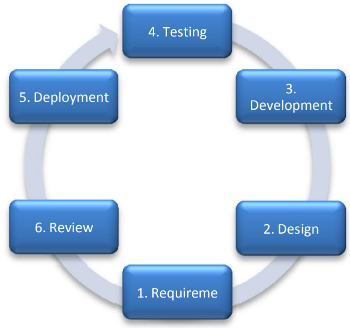

Figure 1 :Agile Methodology

Agile methodology enables a structured yet flexible approach to project management, allowing for iterative development and continuous improvement. Each module is developed with focused attention on functionality and design, following a scheduled plan that specifies when and how it should be refined. User feedback is actively incorporated, often through prototype reviews, which allows developers to make adjustments as needed. This approach fosters clear communication between developers and users, improves transparency, and enhances the likelihood of meeting user expectations while reducing errors by addressing each module separately.

Objectives

The system is designed to provide accurate, real-time weather predictions and natural disaster alerts by leveraging reliable weather data sources and predictive models, allowing users to anticipate potential disasters such as floods, cyclones, or droughts. It features a user-friendly interface that ensures easy navigation, enabling individuals with limited technical knowledge to access critical information quickly. Additionally, the system supports decision-making for emergency responders and policymakers by offering vital insights and forecasts, facilitating better resource allocation, coordination, and disaster management. Through its predictive capabilities, the system helps reduce the financial and infrastructural impact of disasters by enabling effective preparedness measures, such as reinforcing infrastructure, evacuating at-risk populations, and safeguarding assets before an event occurs

IV. SYSTEM DESIGN

System Architecture

Integrates real-time data collection, processing, analysis, and user notification. Weather data is collected through APIs and sensors in disaster-prone regions, capturing variables such as temperature, rainfall, and wind speed. This data is processed and analyzed using **Threshold-Based Heuristics**and **Machine Learning Models,** such as linear regression, to identify patterns and predict potential disasters. The results are visualized on a user interface, where stakeholders can monitor risks. Alerts are triggered when thresholds are exceeded, enabling timely warnings for disaster management agencies and local authorities to take action.

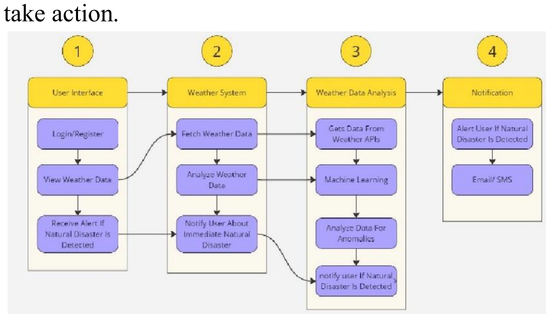

Figure 2 :System Architecture

Use Case Diagram

A use case diagram outlines how users interact with a system to achieve specific goals. It shows the system's boundaries, user roles (actors), and how they interact with the system's functions. Use case diagrams help design and develop systems by capturing all possible user scenarios, ensuring that the system meets user needs. They also clarify the roles and responsibilities of different system components.

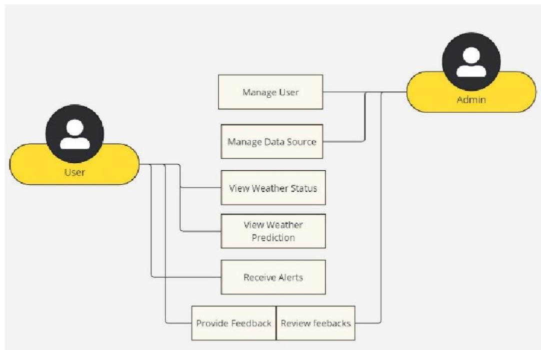

Figure 3: Use Case Diagram

Data Flow Diagram:

The Data Flow Diagram outlines the steps from user input to disaster alert display. Users access the system to request predictions or view alerts, triggering data retrieval from the OpenWeatherMap API, including parameters like temperature, rainfall, and wind speed. This data undergoes preprocessing for accuracy, then enters an analysis phase where machine learning algorithms—such as linear regression and threshold-based heuristics—assess potential disaster risks. The analyzed results are displayed on the user interface, providing clear, timely predictions and alerts. This streamlined data flow supports proactive disaster management and improves community preparedness through reliable, real-time information.

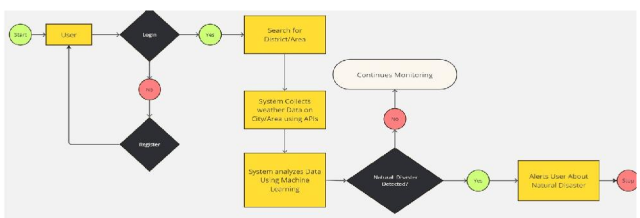

Figure 4: Data Flow Diagram of the System

Model parameters were carefully chosen to improve prediction accuracy. For instance, the linear regression model for rainfall prediction was configured with optimized hyperparameters based on cross-validation results, and threshold-based heuristics were calibrated using historical data on weather thresholds to minimize false-positive rates.

V. SCREENSHOTS

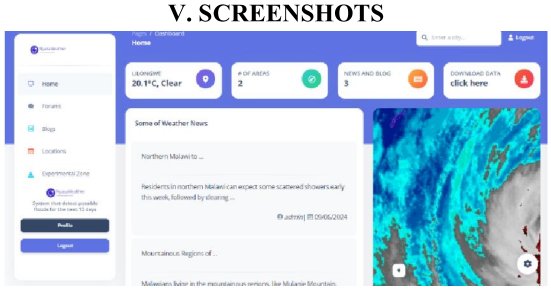

Figure 5: home page

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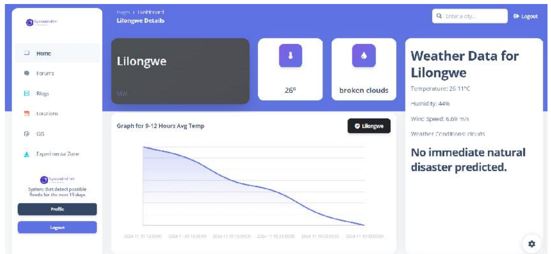

Figure 6 : City page

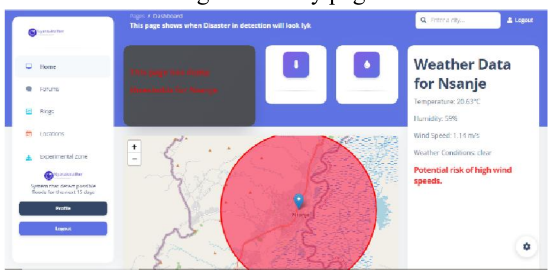

Figure 7: Experimental page

VI. SYSTEM DEVELOPMENT

Modules Description

This is an in depth look at the specific component that comprises of the entire system. My system providing the foundation for accurate natural disaster prediction . Through a combination of machine learning and data mining this module ensures that information is optimally prepared for further processing. By seamlessly integrating with other components, it contributes significantly to the overall effectiveness and reliability of the system.

1 . Feedback Mechanism Module

Confirmation Messages: Provides feedback to users upon successful submission of data to reassure them that their input has been received. Error Messages Communicates any issues or errors encountered during the data submission process, guiding users on how to rectify them. User Communication establishes channels for users to communicate with system administrators or support staff for assistance or clarification regarding data submission.

2. User Authentication and Authorization

User authentication verifies the identity of users before allowing them to submit data, ensuring data integrity and security and Authorization determines the level of access or permissions granted to users based on their roles or privileges within the system.

3. Database management

The Database Management module is a critical component in the system, providing the foundation for the storage and retrieval of captured license plate information. By implementingefficient data organization, retrieval, validation, and security measures, this module ensures the integrity and accessibility of historical vehicle identification data. By seamlessly integrating with other components, it significantly contributes to the overall effectiveness and reliability of the system.

4.User interface

The User Interface module is a critical component in the system, providing users with a platform to interact with and manage the system's operations. Through in configuration,real-timemonitoring, data retrieval, and reporting functionalities, the UI plays a pivotal role in ensuring the effectiveness and usability of the system. By seamlessly integrating with othercomponents, itcontributes significantly to the overall user experience and reliability of the system.

Algorithms

Threshold-Based Heuristics

Work by comparing real-time weather data (such as temperature, rainfall, and humidity) to predefined limits that indicate the risk of a disaster. These thresholds are based on historical data or scientific studies, which specify critical values for various factors. For instance, if rainfall exceeds a certain amount or temperatures rise above a certain limit, the system triggers an alert, indicating a heightened risk for events like flooding or wildfires. This method helps quickly assess potential disaster risks by reacting to immediate data and known danger levels.

VII. MACHINE LEARNING

Linear Regression is employed to predict future weather patterns and their potential to cause natural disasters. By training a model on historical weather data and disaster occurrences, linear regression can predict key variables like rainfall and temperature. These predictions can help anticipate conditions that could lead to disasters before they happen. Combining both approaches—real-time threshold monitoring and predictive modeling—enhances the accuracy and timeliness of disaster forecasting, allowing for both immediate alerts and proactive risk assessment.

VIII. RESULTS

The results of various tests conducted on the system demonstrate its functionality and reliability. In the Data Retrieval Test, the system successfully retrieved current weather data using the API, ensuring accurate data retrieval. The User Interface Test confirmed that navigation links and buttons are clearly visible and functional, allowing users to easily navigate through the system without encountering any errors. During the Browser Compatibility Test, the system displayed properly across different browsers without issues, ensuring consistent functionality. The Usability and Accessibility Test showed that users, regardless of their technical background, could interact with the interface easily, without requiring extensive guidance. Lastly, in the Prediction Display Test, the system displayed prediction results clearly, accurately showing the probability or severity of predicted events without any errors. These tests indicate that the system operates effectively and provides a user-friendly experience. Advantages of the system include its seamless integration with multiple browsers, the ability to handle real-time weather data efficiently, and its user-friendly interface, which ensures accessibility for individuals with varying levels of technical expertise. Additionally, the system's predictive capabilities enable early detection of weather-related risks, empowering users to take proactive measures.

IX. ACKNOWLEDGEMENTS

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About the Author

Cedric Ngendahimana is an undergraduate student at DMI-St. John the Baptist University, Lilongwe campus, Malawi, pursuing a Bachelor of Science in Computer Science. This project was undertaken as part of his final year requirements, reflecting his dedication to applying innovative technology solutions to real-world challenges in fulfillment of his academic goals.

About CO-Author

Mrs. Fanny Chatola is a Lecturer in Computer Science at DMI, Saint John The Baptist University. Holding a Master's degree in Computer Science, she specializes in areas various areas in computer science. Fanny's research focuses on innovative solutions to real-world challenges, with a strong commitment to advancing technology and contributing to academic and industry progress

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