Development of Web-based Digital Landslide Early Warning System (LEWS) Dashboard in Neelakantha Municipality, Dhading

1. Introduction

Landslide is known as one of the most common and disastrous hazards in the mountainous region of Nepal resulting in huge losses of human lives and properties on an annual basis typically during monsoon. The frequency and intensity of the landslides are expected to be increased in the coming days because of climate change impacts and unplanned anthropogenic activities implying that landslide risk will increase. For this reason, different risk reduction initiatives have been explored among which Landslide Early Warning System (LEWS) has been regarded as an important one. There are various methods that exist in practice for the slope stability analysis used for landslide hazard mapping; however, LEWS is limitedly known and it is still in the research and development stage. Estimation of rainfall threshold to trigger landslide is the first step in the LEWS development. With the limitedly available historical data, a rainfall threshold model for the Neelakantha Municipality has been developed considering the 5-day cumulative antecedent rainfall. In addition to that, a Landslide Susceptibility Model (LSM) of the municipality has also been developed with the help of the widely used landslide conditioning factors such as landscape soil physical and hydrological properties. The LSM identifies the potentially unstable locations and makes the community people aware of the likelihood of the landslides.

Advancement in digital technology and the computational environment has given ample opportunities to integrate the developed slope stability model with rainfall threshold. It enables data capture, analysis, and display of the results efficiently and integrates with the user-friendly computer interface. The Geospatial Digital LSM Model along with the real-time climate data and forecast of rainfall obtained from the Department of Hydrology and Meteorology (DHM) helps the municipality officials to understand the likelihood of landslides in the municipality and vulnerable communities in advance. In order to monitor the likelihood of landslides during monsoon, threshold rain has been established for the Neelakantha Municipality of Dhading District with the help of limitedly available historical landslide data. In order to visualize the likelihood of triggering of landslide a Web-based Digital Dashboard has been developed.

The dashboard will further integrate data from various sources, including weather stations, soil moisture sensors, and ground displacement monitoring instruments installed in the research catchment of upper Arun Khola. This data will be continuously updated and analyzed and provide a comprehensive view of the current conditions within the dashboard. The dashboard employs the algorithms and models developed and processed in the back end and assesses landslide risk based on real-time and forecast rainfall. This involves analyzing various landslide-triggering factors such as rainfall, soil saturation levels, ground movement, and historical landslide data. Whenever the dashboard detects the likelihood of exceedance of the threshold rain, it will generate alerts and warnings. The Local Emergency Operation Center (LEOC) of the municipality can visualize the entire phenomenon for better preparedness. The alerts can also be linked with mobile SMS to the concerned authority allowing emergency responses and prioritizing their actions.

2. Objectives

The main objective of the digital dashboard is to develop the landslide early warning algorithm based on real-time and forecast rainfall and visualize the likelihood of landslides in the municipality to generate different types of warnings to be issued by the LEOC.

3. System Design and Architecture

The system involves the actual development of the web-based application in such a way that the user can assess the system from anywhere in the world and visualize potential landslides in the municipality. The system primarily comprises of the creation of a flexible system's architecture ensuring the provision of future adjustment, modification and corrections if required to scale up. A user-friendly interface has been developed. Moreover, a PostgreSQL database integrated with Kobo was applied to efficiently handle the anticipated huge data volumes. The system has been built using a combination of Postgres Database with Python (Django) to manipulate and process the data received at the backend, REST framework for Application Programming Interface (API), development, HTML, CSS, and JavaScript (ReactJS) for frontend development, and Maplibre for mapping frontend with GeoServer for map data service.

The system architecture for Geo-Alert has now served as the basis for defining the application structure, functionality, data input and management, and overall development (Figure 1).

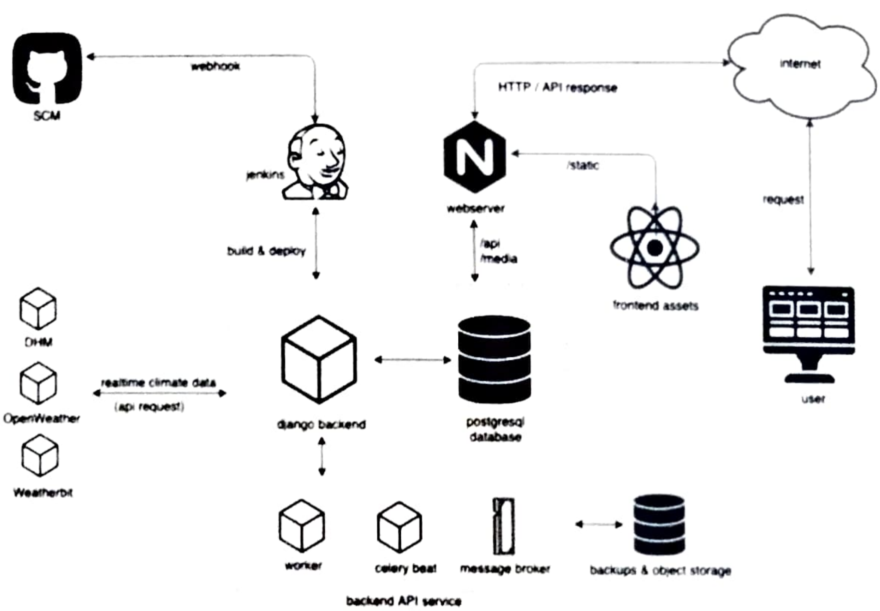

Figure 1: System Architecture Diagram for LEWS

Technical Stack

The system applies a technology stack of Postgres Database with Python (Django) backend, REST framework for API development, HTML, CSS, and JavaScript (ReactJS) for frontend development and Maplibre for mapping frontend with GeoServer for map data service. Rechart JS has been used for data visualization. The latest and stable open-source tools and libraries are incorporated in the flexible libraries as and when required:

- Operating System: Ubuntu Server 22.04.2 LTS
- Server: VPS server
- Version control and Issue Tracking: GitHub Private Repository
- Database: PostgreSQL with PostGIS extension
- Web Backend: Python (Django) app
- APIs: RESTful API
- Web Frontend: React JS, HTML, CSS, Maplibre (Web Mapping)
- Web Server: Nginx
- Build & Test: Github Actions, Jenkins

Data Analysis, Threshold Rainfall Algorithm and Configuration

The project team conducted an in-depth analysis of various datasets including historical landslide data, climate information, and geological along with hydrological factors to trigger landslides. Freely available data from OpenWeather, Weatherbit and the DHM are processed and integrated into the system.

By correlating historical landslide data with different influencing factors an algorithm for the developed rainfall threshold model has been written in the PYTHON programming at the back-end for data processing. The algorithm processes the data received at the server and allows to visualize of the state of threshold rainfall at the front end. The dashboard allows the visualization of accumulated and sub-hourly rainfall and soil moisture content at sub-hourly, hourly, and daily intervals. It also enables the comparison of real-time rainfall data versus and forecast one within the analytics section. When rainfall exceeds the threshold value, a signal will pop up and an alert message will be generated indicating the likelihood of the landslides.

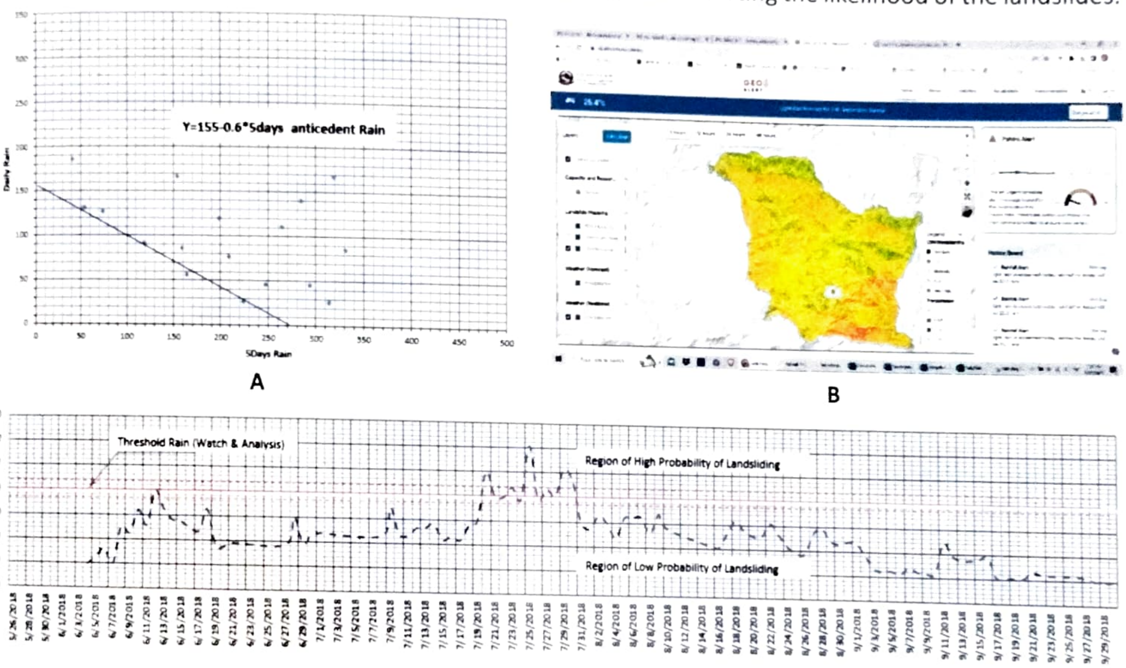

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Figure 2: A: Threshold Rain Model, B: The Home page of Dashboard, and C: Visualization of exceedance of rainfall that could trigger landslides.

The integration of real-time from the stations and forecast from the DHM and the data obtained from multiple sources, including OpenWeather, Weatherbit has facilitated the dynamic display of current as well as forecast weather conditions and potential slope failures. The web portal offers a real-time visualization of rainfall intensity, accumulated antecedent rainfall, and soil moisture behavior in response to rainfall along with other interactive map displays through filtering options, and concise progress and beneficiary summaries. Rechart JS has been used for the data visualization. In the web-based Dashboard, users are able to assess historical weather data and compare them with real-time observations to monitor trends and potential landslides areas.

These features collectively provide a comprehensive understanding of the Geo-Alert Tool and highlight its major components such as the Home page, Analytics, Visualization and Instrumentation. The dashboard also showcases details about landslides, municipal characteristics related to the demographics and its landslide susceptibility map.

In the analytics section of the web portal/digital dashboard, graphs depicting rainfall intensity, soil moisture levels, and weather patterns are dynamically demonstrated and subsequently updated. The analytics page presents side-by-side graphs showcasing forecasted rainfall and actually observed ones. The analytics page offers a dedicated section of threshold monitoring, displaying the established rainfall-landslide threshold model.

Testing, Feedback and Training to the Users

Continuous quality assessments have been undertaken throughout the development phase which include rigorous testing, feedback incorporation, and iterations. Various tools and methods like function, system, integration, and regression testing have been employed to ensure the delivery of a stable and functional application.

A training session at the municipality level was organized to enhance users' familiarity on the developed tools. Training covered various areas of data collection, management, display and system utilization for the decision-making process.

4. Remarks

The Digital Landslide Early Warning System (LEWS) Dashboard has been designed to disseminate efficient, authenticated and accurate warnings to the communities in landslide-prone areas, thereby minimizing potential loss of lives and properties. It provides real-time visualization of critical data to trigger landslides which include rainfall intensity, accumulated antecedent rainfall amount and changes in soil moisture. The inclusion of interactive maps, charts, infographics and photographs, alert messages and notice boards empowers the users to understand the dashboard easily, disseminate the early warnings and take necessary actions for response.

Throughout the development process, the team has recurrently addressed key technical challenges and considerations to develop robust and reliable tools and methodologies. Some of the recommendations to develop the application in a more effective way in the future are listed below:

- Server maintenance and subscription management are the key in the system. It is therefore recommended that the server and its underlying infrastructure should be provisioned by the Neelakantha Municipality;
- Incorporation of user feedback to continuously improve the dashboard's applicability at a wider level and features as the data resolution should be maintained on a regular basis;
- The dashboard can be further equipped with the beep alert feature wherever the system detects the exceedance of threshold rain and the likelihood of landsliding is high;
- It is important to maintain spatial and temporal databases related to the landslides (such as location, size and date of landslides) in the future as it helps to improve the rainfall threshold model thereby a robust Dashboard.

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