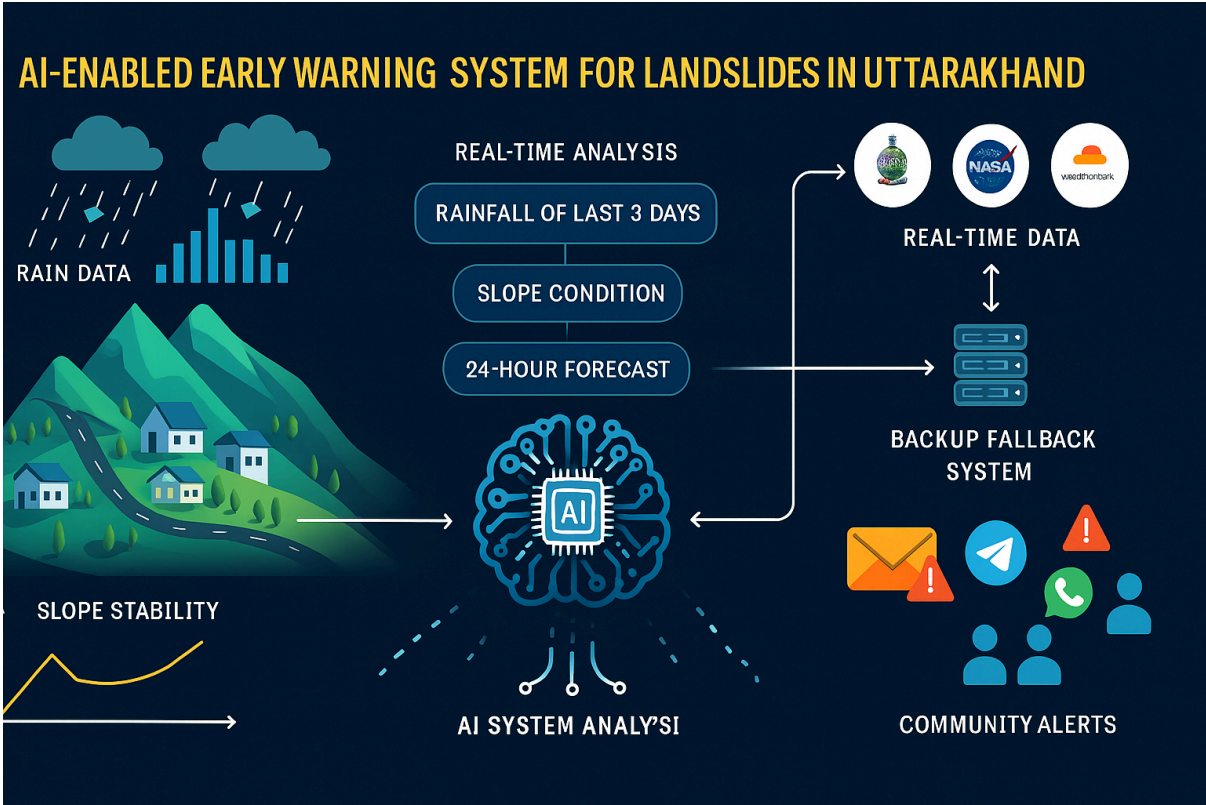


AI-Enabled Hybrid Early Warning System: Landslide Risk Prediction — Uttarakhand



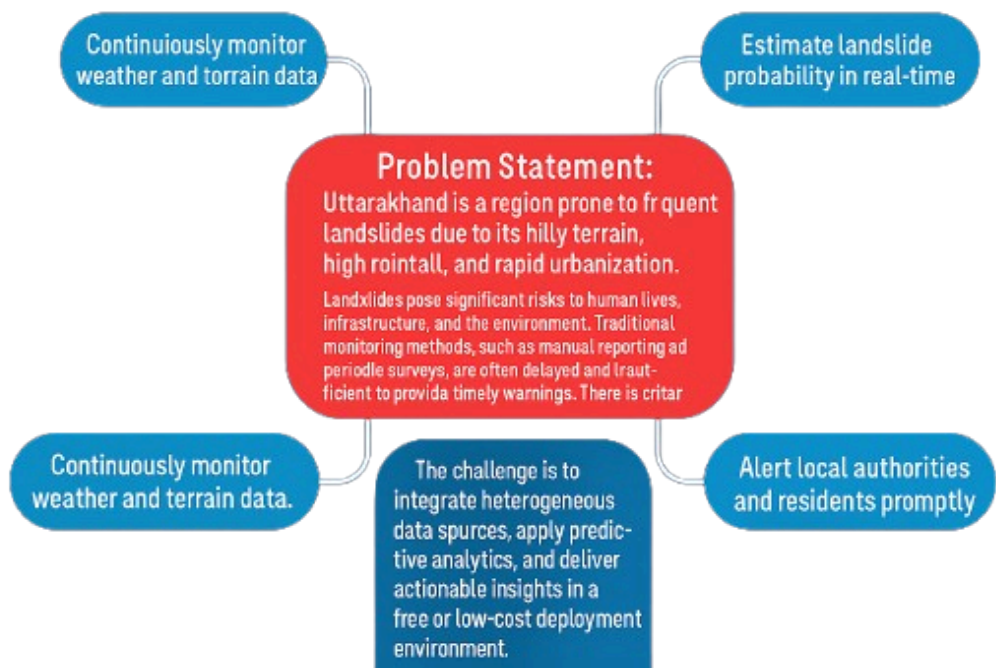
1. Title

AI-Enabled Hybrid Early Warning System for Landslide Risk Prediction in Uttarakhand

2. Problem Statement

Uttarakhand is a region prone to frequent landslides due to its hilly terrain, high rainfall, and rapid urbanization. Landslides pose significant risks to human lives, infrastructure, and the environment. Traditional monitoring methods, such as manual reporting and periodic surveys, are often delayed and insufficient to provide timely warnings. There is a critical need for a system that can:

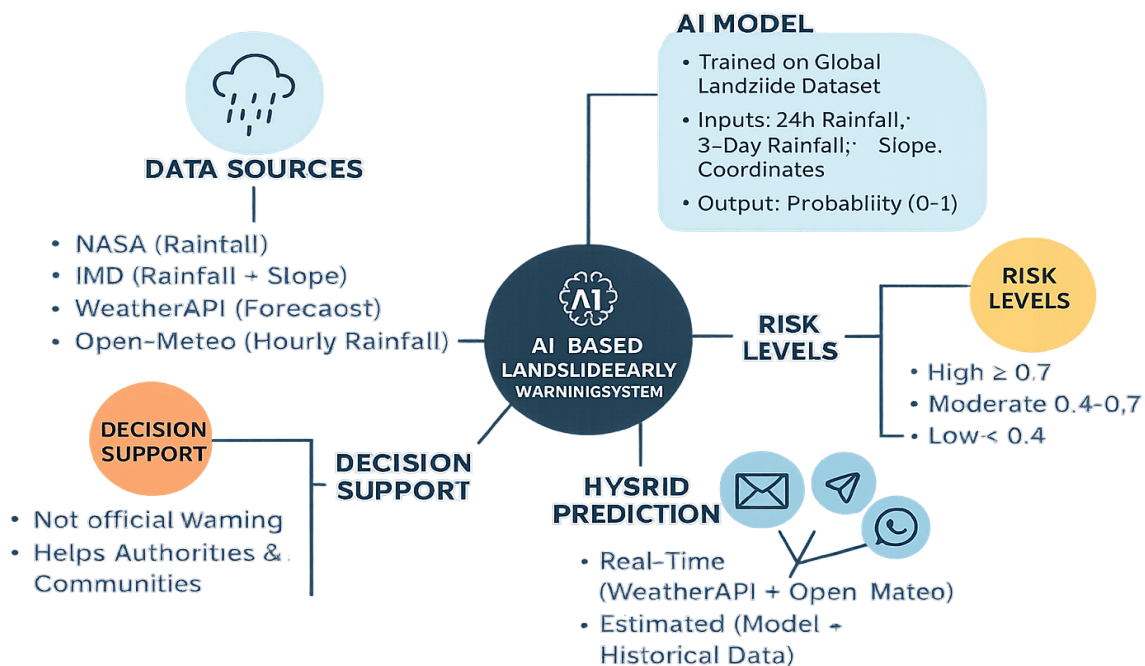
- Continuously monitor weather and terrain data.
- Estimate landslide probability in real-time.
- Alert local authorities and residents promptly.



The challenge is to integrate heterogeneous data sources, apply predictive analytics, and deliver actionable insights in a free or low-cost deployment environment.

3. Proposed Solution

We have developed a **hybrid AI-based landslide risk prediction system** designed to integrate multiple data sources and provide probabilistic risk alerts.



Data Integration

The system aggregates data from various sources:



- **NASA GPM IMERG:** Satellite-based global precipitation measurements.
- **India Meteorological Department (IMD):** Historical rainfall data and slope information for regional accuracy.
- **WeatherAPI:** Forecast rainfall for the next three days.
- **Open-Meteo:** Hourly precipitation data for short-term rainfall accumulation.

Artificial Intelligence Model

- Trained on the **Global Landslide Catalog Dataset** ([Global_Landslide_Catalog_Export.csv](#)).
- **Input Features:** 24-hour rainfall, 3-day cumulative rainfall, slope angle, and district coordinates.
- **Output:** Landslide probability (0–1).
- **Fallback:** Heuristic scoring method in case of model or data unavailability.

Hybrid Risk Estimation

- **High Risk:** Probability ≥ 0.7
- **Moderate Risk:** $0.4 \leq \text{Probability} < 0.7$
- **Low Risk:** Probability < 0.4

Automated Alert System

- **Email Notifications:** Implemented using the **SendGrid API**. Recipients can be added dynamically in the application.
- **Telegram Alerts:** Optional; free-tier deployment may have API limitations.
- **Debug Logging:** Captures which data source provided the prediction and whether alerts were successfully sent.

Decision Support

- The system provides guidance and alerts based on probabilistic predictions.
- Predictions are **not official warnings** but support informed decision-making for authorities and communities.

Real-Time and Estimated Predictions

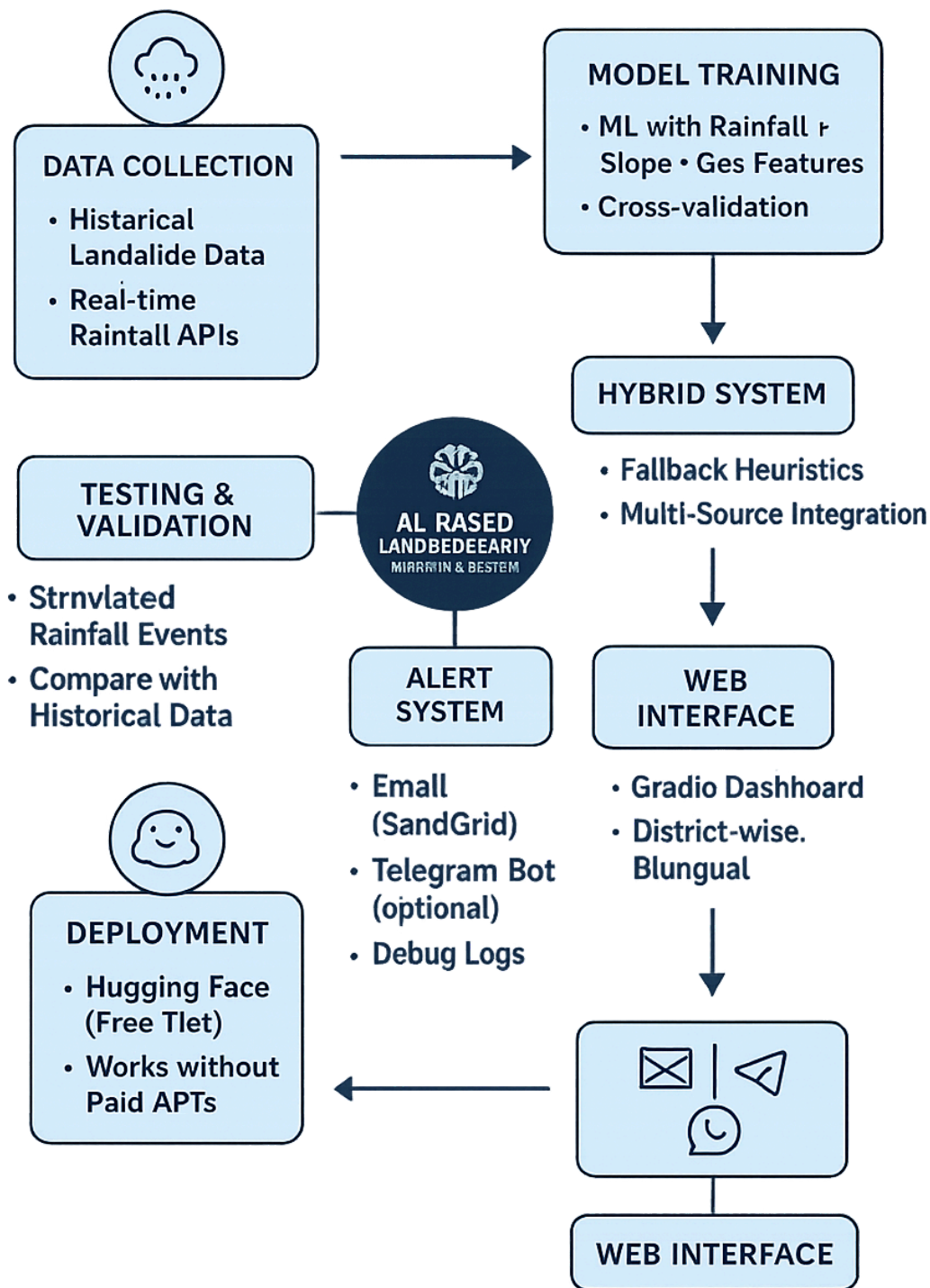
- **Real-Time Component:** Short-term rainfall data from WeatherAPI and Open-Meteo.
- **Estimated Component:** Historical model predictions provide probabilistic risk estimations.
- The combination creates a **hybrid early warning system** for dynamic and informed response.

4. Tools/Technology Used

- **Programming Language:** Python 3.10
- **Machine Learning Library:** scikit-learn, joblib
- **Web Interface:** Gradio
- **Data Sources:** NASA GPM IMERG, WeatherAPI, Open-Meteo, IMD, Global Landslide Catalog
- **Automated Messaging:** SendGrid API for emails, Telegram Bot API (optional)
- **Data Handling:** Pandas for data preprocessing and feature management
- **Environment:** Free-tier deployment (Hugging Face Spaces, or local deployment)

5. Step-by-Step Plan

1. **Data Collection:**
 - Download and preprocess historical landslide data (`Global_Landslide_Catalog_Export.csv`).
 - Integrate API access to real-time rainfall and weather forecast sources.
2. **Model Training:**
 - Train a machine learning model using rainfall, slope, and geographical features.
 - Validate model performance using cross-validation on historical data.
3. **Hybrid System Development:**
 - Implement fallback heuristics for risk estimation if model predictions fail.
 - Integrate multi-source rainfall data for dynamic input.



4. Web Interface Development:

- Use Gradio to display probabilistic risk predictions.
- Show district-specific results in a professional, bilingual (English/Hindi) layout.

5. Automated Alert System:

- Configure SendGrid API for email notifications to multiple recipients.
- Optionally integrate Telegram bot notifications.

- Implement debug logging for transparency on which data source triggered the alert.

6. Testing and Validation:

- Perform test runs to simulate rainfall events and ensure alerts are delivered.
- Verify probabilistic predictions against historical landslide occurrences.

7. Deployment:

- Deploy system on free-tier Hugging Face Spaces for demonstration.
- Ensure that system works without paid SMS or premium API limitations.

6. Learning Outcomes

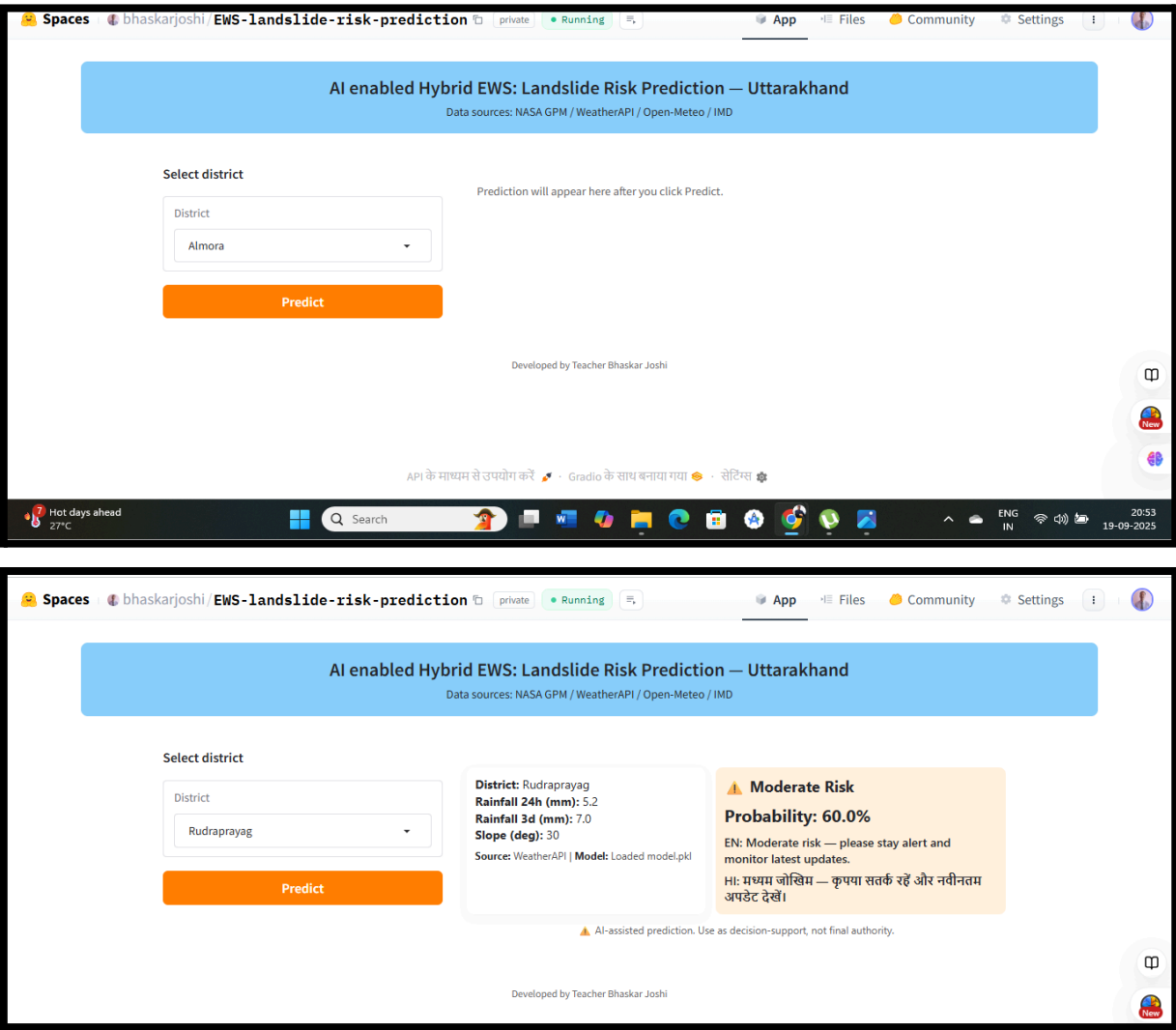
- Understanding the challenges of real-time disaster prediction in hilly regions.
- Integrating heterogeneous data sources into a unified prediction system.
- Applying machine learning for probabilistic hazard estimation.
- Designing a hybrid system that combines AI predictions with heuristic fallback mechanisms.
- Implementing automated alerting for end-users via email and messaging platforms.
- Developing a user-friendly and professional web interface for decision support.
- Awareness of limitations of free-tier environments and handling of API restrictions.

7. Link to Hackathon Theme / SDGs

- **Hackathon Theme Alignment:** Disaster management, environmental monitoring, and early warning systems.
- **Sustainable Development Goals (SDGs):**
 - **Goal 11:** Sustainable Cities and Communities – by improving safety in landslide-prone regions.
 - **Goal 13:** Climate Action – by monitoring rainfall and environmental factors.
 - **Goal 9:** Industry, Innovation, and Infrastructure – through AI and hybrid predictive systems.



8.Screenshot of Real Application



Spaces bhaskarjoshi EWS-landslide-risk-prediction private Running App Files Community Settings

AI enabled Hybrid EWS: Landslide Risk Prediction — Uttarakhand

Data sources: NASA GPM / WeatherAPI / Open-Meteo / IMD

Select district

District: Pithoragarh

Predict

District: Pithoragarh
Rainfall 24h (mm): 10.7
Rainfall 3d (mm): 11.5
Slope (deg): 33
Source: WeatherAPI | **Model:** Loaded model.pkl

High Risk
Probability: 79.0%
EN: You are at risk — please take necessary safety steps immediately.
HI: आप जोखिम में हैं — कृपया आवश्यक सुरक्षा कदम तुरंत उठाएँ।

AI-assisted prediction. Use as decision-support, not final authority.

Developed by Teacher Bhaskar Joshi

Spaces bhaskarjoshi EWS-landslide-risk-prediction private Running App Files Community Settings

AI enabled Hybrid EWS: Landslide Risk Prediction — Uttarakhand

Data sources: NASA GPM / WeatherAPI / Open-Meteo / IMD

Select district

District: Dehradun

Predict

District: Dehradun
Rainfall 24h (mm): 6.3
Rainfall 3d (mm): 6.3
Slope (deg): 25
Source: WeatherAPI | **Model:** Loaded model.pkl

Low/No Significant Risk
Probability: 18.0%
EN: No significant risk detected based on current data — please update for latest prediction.
HI: वर्तमान डेटा के अनुसार कोई महत्वपूर्ण जोखिम नहीं पाया गया — कृपया नवीनतम भविष्यवाणी के लिए अपडेट करें।

AI-assisted prediction. Use as decision-support, not final authority.

Developed by Teacher Bhaskar Joshi

9. [Tutorial Video link](#)

10. [Source Code link](#)

video link - <https://youtu.be/sfukwrSuOco>