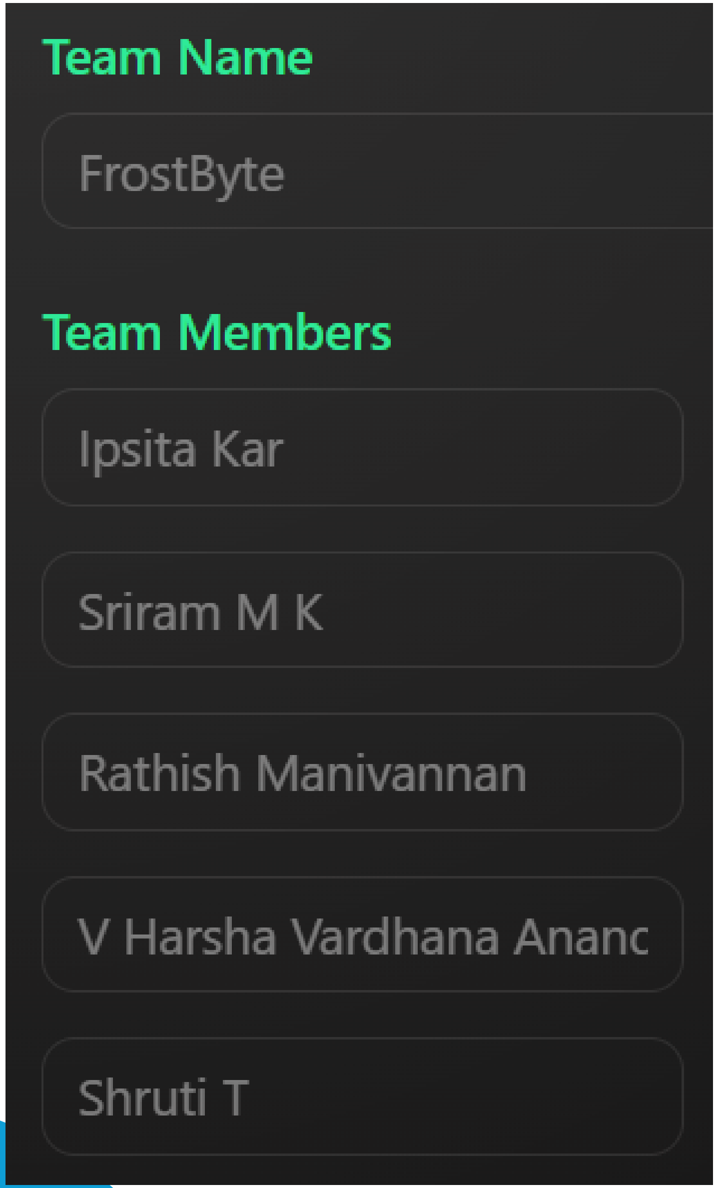
Team Name

FrostByte

Team Members

Ipsita Kar

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V Harsha Vardhana Ananc

Shruti T

HACK $DAY
HACKATHON 2024

- **Problem Statement Title –**
  - Early Warning System for Glacial Lake Outburst Floods
- **Theme –** Disaster Management
- **Team Name – FrostByte**

GLACIER LAKE OUTBURST FLOOD DETECTION

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e

Overview:

Remote sensing technology, a Network of IoT Sensors, Machine Learning Model.

Purpose:

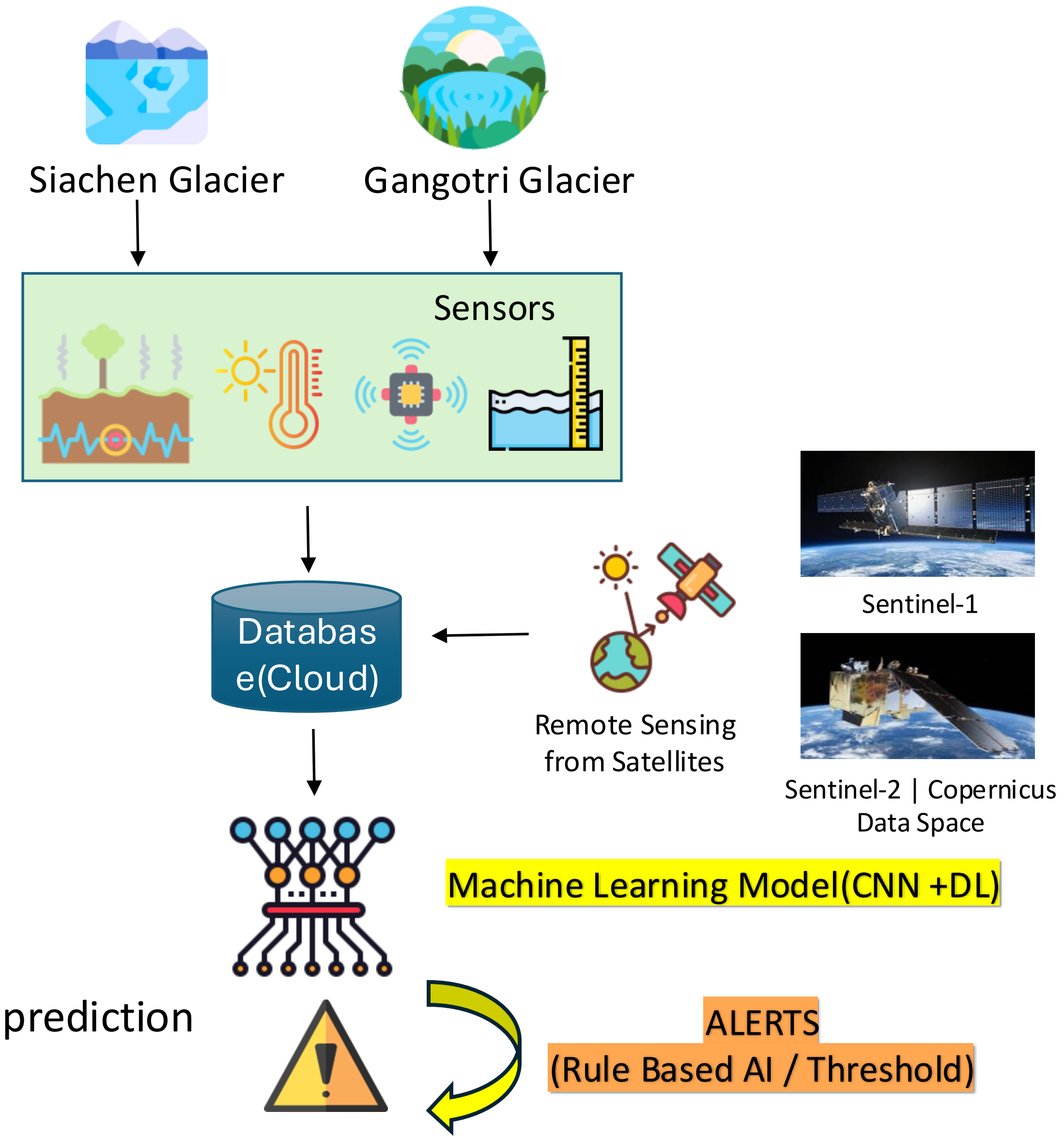
Monitor glacial lakes and their surroundings in real-time, detecting critical changes that may **indicate a warning**.

Proposed solution:

- IoT sensors to measure key parameters
- Data is sent to the **cloud through an Edge Gateway**
- Remote sensing data from satellites
- **ML models to analyze data to detect early signs of GLOF**
- When a threat is identified, a warning is triggered.

Innovation and Uniqueness:

- Usage of **Edge computing**
- Combination of **Satellite data + Sensor data** for accurate data prediction
- **Real time** data analysis using ML



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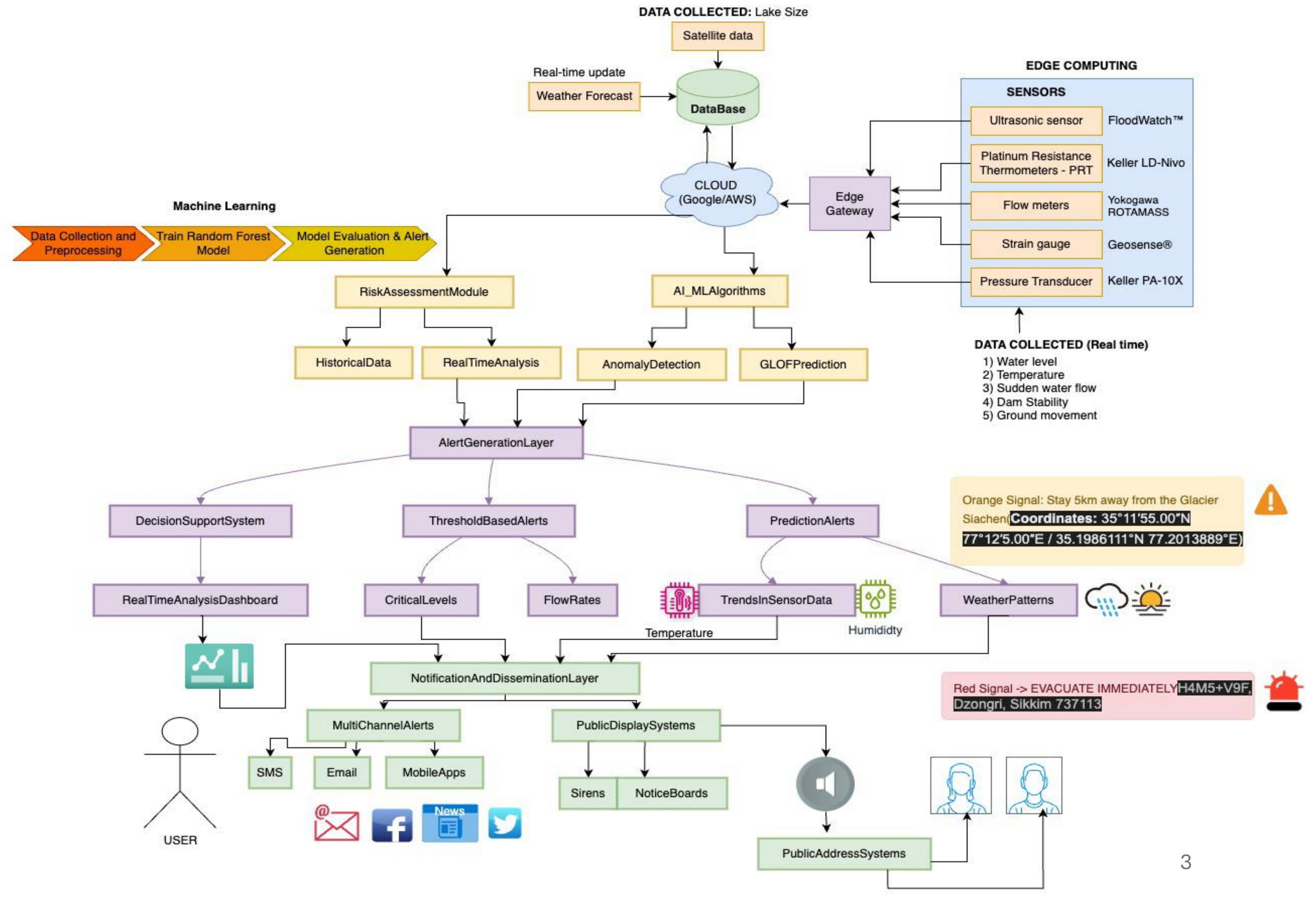
TECHNICAL APPROACH

Website Integration: MERN(Express.js,React,Node.js)
ML Frameworks: TensorFlow, Py Torch, Random Forest Classifier ,API for Sentinel(Hub)
Backend Frameworks: Flask, Django for web-based alert system;
Data Processing: Apache Kafka for real-time
Hardware: IoT sensors (As per block diagram)
Database: MongoDB
Cloud: Cloud-based storage (AWS) , Rest APIs
Communication: REST, Edge computing

Satellite image from Uttarakhand (Chamoli district)



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FEASIBILITY AND VIABILITY

Feasibility:

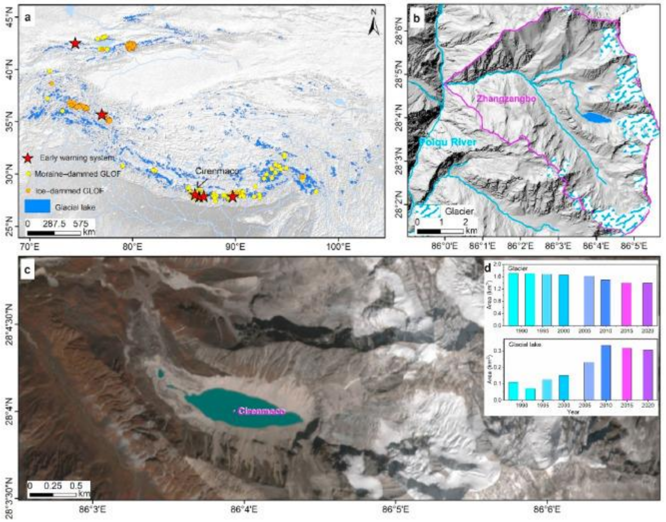
- **Technical Deployment**:
  - **IoT Sensors** gather real-time data; processed using **Edge Computing**.
  - **MERN Stack** enables website integration and real-time alerts.
  - **ML Models** predict GLOF events using satellite data (Sentinel API).
- **Financial Setup:**
  - Initial setup costs for IoT, satellite integration, and cloud storage (AWS).
  - Long-term savings via automation and disaster prevention.
- **Market Scalability**:
  - High demand from govts, environmental agencies, and disaster response teams.
- **Operational Events:**
  - Real-time data processing with **Apache Kafka**.
  - Cloud storage on AWS with **MongoDB** for scalable database needs.

Potential Challenges and Risks:

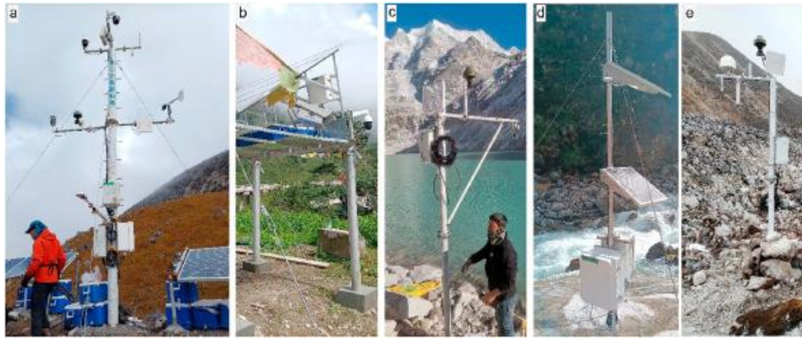
1. **Environmental Challenges:**
   - Damaged sensors and disrupted data collection.
2. **Data Reliability:**
   - False positives from ML models causing unnecessary alerts .
3. **Financial Constraints:**
   - Initial deployment costs for IOT and Cloud infrastructure.

Strategies for Overcoming These Challenges:

1. **Robust Hardware:**
   - Weather-resistant materials & Ruggedized IoT sensors, **Edge Computing** for local processing.
2. **Financial Support:**
   - Partner with environmental agencies for funding.
   - Phased deployment to manage costs.
3. **Alternative Communication:**
   - Satellite-based transmission, to ensure reliable data flow.
   - Secure data through encryption and **REST APIs**.



Cirenmaco(1988) is located in the Zhangzangbo Valley, central Himalaya.



EWS installed at Cirenmaco (moraine dam)

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IMPACT AND BENEFITS

Impact

- **Early Detection**:
  - The **in-situ** and **real-time monitoring** guarantee captures the precursors of **ice collapse and glacial** lake outburst and **raises alarms** in advance for downstream communities.
- **Environmental Benefit**:
  - The **EWS** system is **less expensive** than lake dam immobilization and artificial drainage projects, and it provides more valuable **environmental** monitoring data in high mountain areas.
- **Risk Mitigation**:
  - Due to **climate warming** and ongoing glacier recession, glacial lakes in the Tibetan Plateau and its surroundings are in a state of rapid expansion and numerous **potential glacial lakes** buried within the glacier beds are projected to be **exposed in the future.**

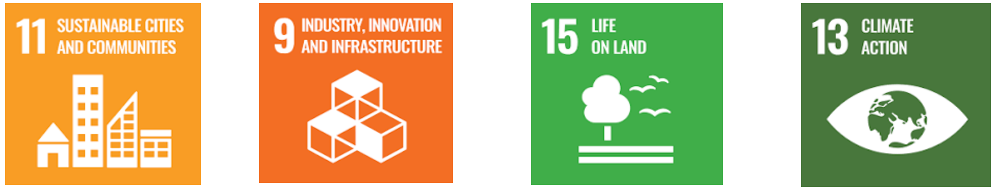
Target Audience

- **Downstream Communities**:
  - Populations living near glacial lakes in regions like the Himalayas, Tibetan Plateau, Andes, and other high mountain areas.
- **Local Governments**:
  - Authorities responsible for disaster mitigation and infrastructure protection in vulnerable regions.
- **Environmental Monitoring Agencies**:
  - Organizations focused on preserving ecosystems and monitoring climate change impacts in glacial regions.

Future Scope & Benefits:

- **Global Expansion of EWS**:
  - Potential to expand **E**arly **W**arning **S**ystems to other regions beyond the Himalayas, where glacial lakes are prevalent and within **southern states** of India where flooding is common.
- **Climate Change Response**:
  - With glaciers receding globally due to climate change, EWS can be crucial in protecting newly exposed and expanding glacial lakes.
- **Environmental & Economic Impact:**
  - Preserving ecosystems and biodiversity in glacial regions & Reduction in economic losses by preventing infrastructure damage.

Our problem statements helps achieve the following SDG's:



Concerning Facts:

- Over the past few decades, the number and area of glacial lakes on the plateau have increased by ~10.7% and ~15.2%, respectively .
- The Himalayas have the highest concentration of contemporary glacial lake outburst floods among all subregions
- Research on prevention and mitigation measures for GLOFs from high-hazard/risk glacial lakes remains lacking .

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RESEARCH AND REFERENCES

Papers & Publications

- B. Kumar, A. Sathyan, T. S. M. Prabhu and A. K. K, "Design Architecture of Glacier Lake Outburst Flood (GLOF) Early Warning System Using Ultrasonic Sensors," 2020 IEEE Recent Advances in Intelligent Computational Systems (RAICS), Thiruvananthapuram, India, 2020, pp. 195-200,doi: 10.1109/RAICS51191.2020.9332472.
- Noorain, N & Thouheed Ahmed, Syed & Shenoy, H & Ariff, Syed. (2021). Glacier Monitoring Using Sensor Techniques Powered by Renewable Energy Resources: A Prototype. 10.4108/eai.16-5-2020.2304032.

Datasets (IoT Sensors)

- https://ieee-dataport.org/documents/glacial-lakes-detection-dataset
- https://drdo.gov.in/drdo/avalanche-hazard-data-cards
- https://drdo.gov.in/drdo/avalanche-hazard-data-cards
- https://www.sciencedirect.com/science/article/pii/S1569843222002734

Datasets (Satellite Imagery)

- https://earthexplorer.usgs.gov/
- https://asf.alaska.edu/
- https://dataspace.copernicus.eu/

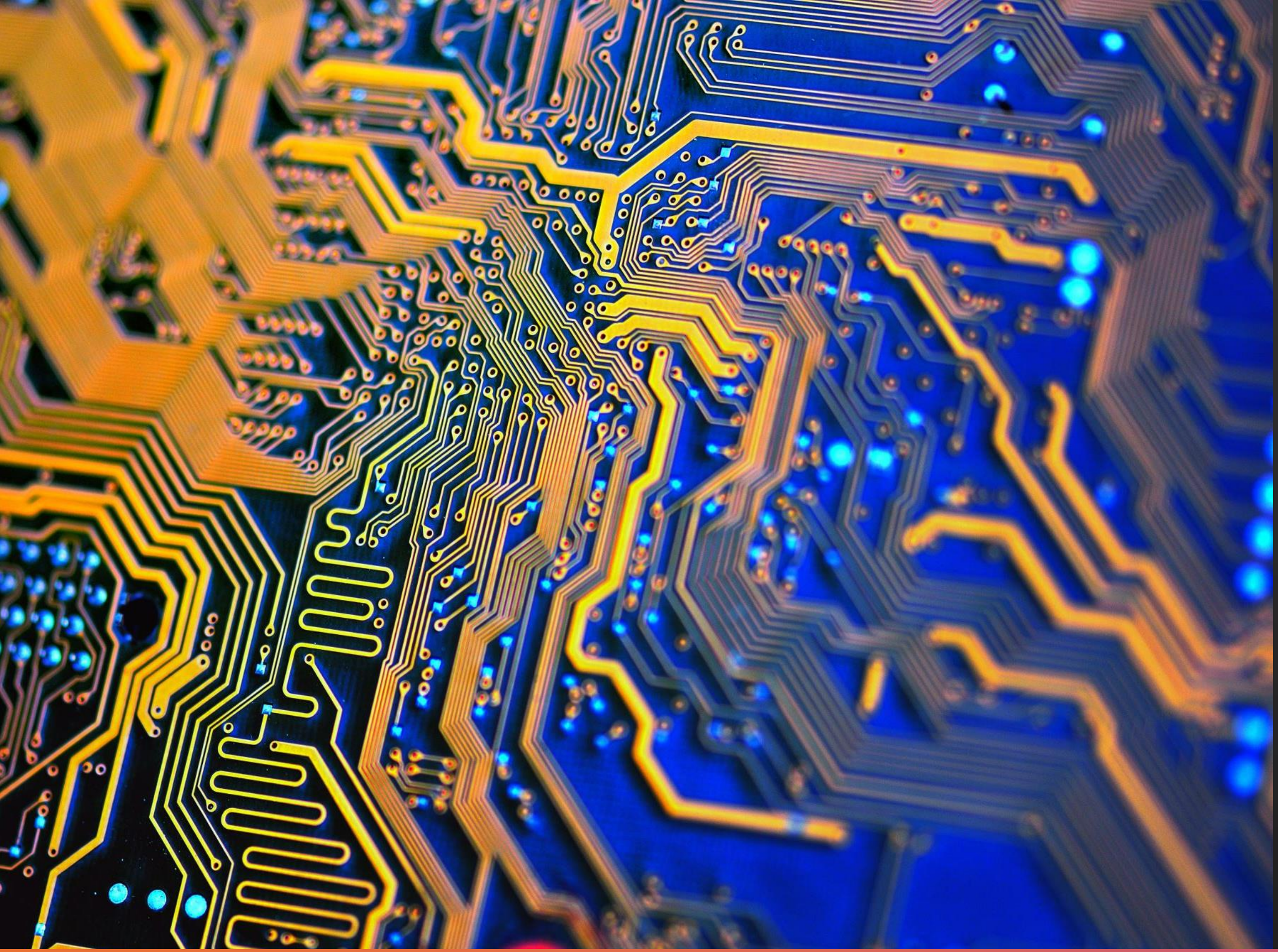
News Articles

- https://www.sciencedirect.com/science/article/pii/S2212420922001339

South Lhonak in Sikkim

Indian Himalayan range

Parkachik glacier, Ladhak

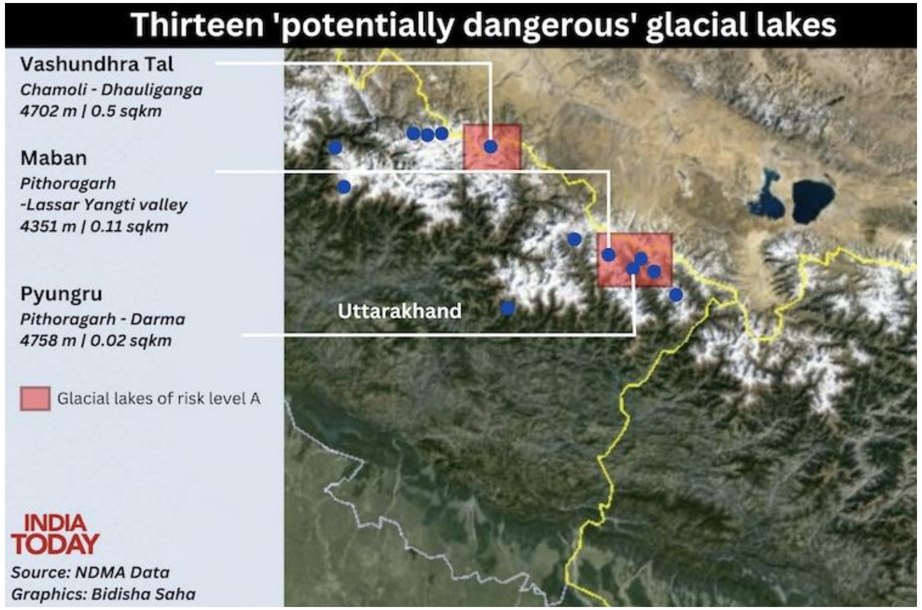


ADDITIONAL PPT

HISTORY – RELATED DISTASTERS

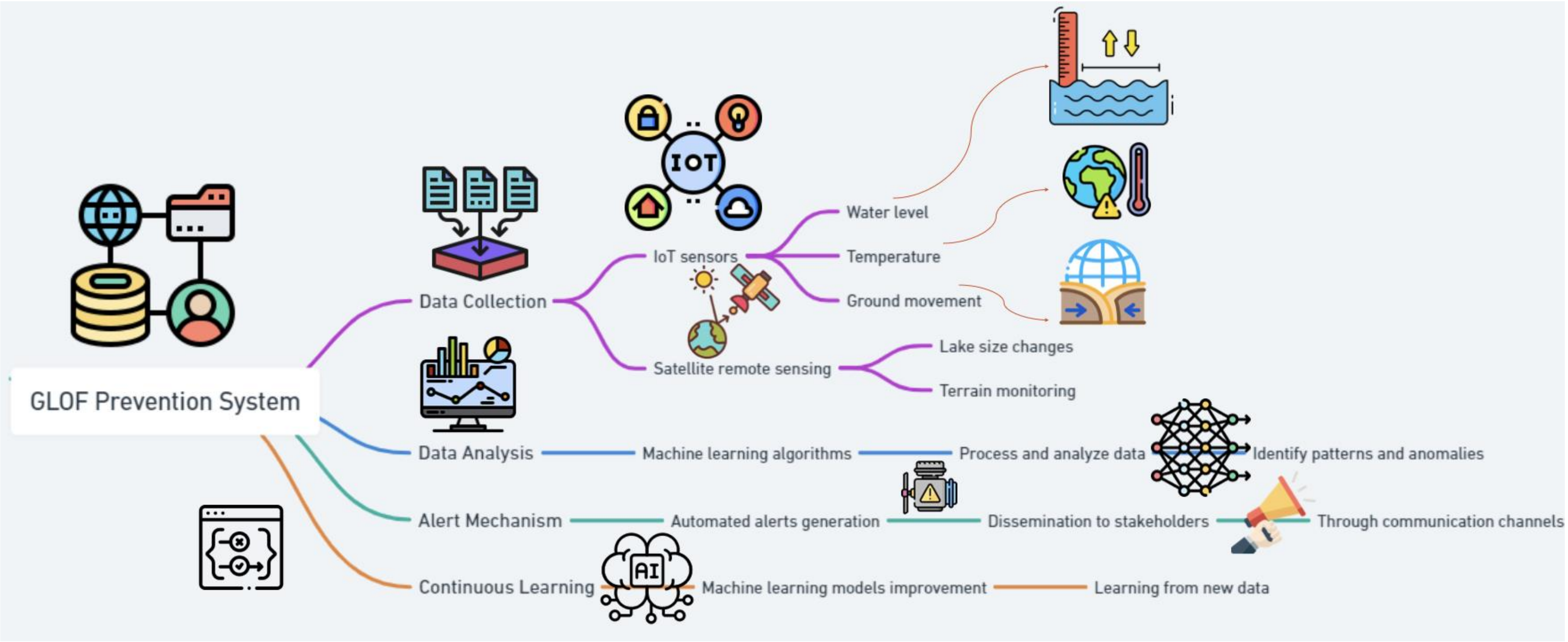
GLOFs are dangerous threats in the Himalayas, capable of devastating the region's growing population.

- **Kedarnath Tragedy, Uttarakhand (June 2013):**
  - Massive destruction, Severe flooding
  - Infrastructural damage.
- **Chamoli Flash Floods, Uttarakhand (February 2021):**
  - Glacier lake rupture triggered flash floods
  - Widespread devastation and regional vulnerability.
- **South Lhonak GLOF, Sikkim (October 2023):**
  - Over 40 lives lost due to failed EWS.
- **Recurrent Sensor Failures, Sikkim (2013, 2016, 2023):**
  - Repeated sensor failures --> Severity of the 2023 disaster



- Out of approximately **7,500 glacial lakes**, Sikkim hosts **10% with 25 deemed high-risk**.
- Uttarakhand's inventory lists **1,266 glacial lakes**, but **13** are categorized as high-risk (**Level A**) by the National Disaster Management Authority (NDMA).

OVERVIEW OF OUR SYSTEM



COLLECTION OF DATA

A key advantage of our project is its use of data from **diverse sources.** The final warning is determined based on all the parameters listed below, with each parameter sourced from a specific channel. Consequently, the system's overall output is derived from multiple parameters rather than relying on a single source.

Parameters for which data is being collected:

1) Weather forecast
2) Lake size
3) Water level
4) Temperature
5) Sudden water flow
6) Dam Stability
7) Ground movement

Sensors are used to get input for these parameters (items 4–7)

Edge computing processes and cleanses data locally before sending it to the cloud, optimizing efficiency and reducing latency.

Our team has conducted **extensive research to identify the most effective methods** for obtaining the most accurate data for each of the following parameters.

The rationale behind our choices is provided in the subsequent slides.

CHOOSING THE BEST SOURCE

1) **Weather forecast**
   - The implementation for receiving data for this parameter is currently underway.
   - As for now, we have chosen to source data from the **Indian Meteorological Department (IMD)**, which is widely recognized as the most **reliable** provider of **real-time** weather information in India.
   - IMD's **MAUSAM platform** offers accurate and **up-to-date data**, making it an ideal choice for our project
   - By using this data, we aim to ensure the highest **accuracy** in weather-related parameters.

2) **Lake size – Surface Area of the lake**
   - Two different types of **satellite data** is being used for accurate prediction.
   - **Sentinel-1**: Provides SAR data, which is crucial for flood detection, especially under cloudy or nighttime conditions. SAR penetrates clouds and provides all-weather, day-and-night observations.
   - **Sentinel-2**: Provides multispectral optical imagery (13 bands), useful for vegetation monitoring, land cover change, and detecting water bodies.

3) **Water level**
   - **India Water Resources Information System (India WRIS)** provides **real-time water level** data for glaciers making it an ideal choice to be integrated with our project
   - It offers up-to-date measurements, which are crucial for monitoring glacial lakes & assessing flood risks.
   - Data helps in understanding changes in glacier water levels and can be used to predict potential GLOFs

CHOOSING THE TYPE OF SENSOR

NOTE: Alongside each sensor, the block diagram in the main PPT includes the **real-life industry-deployable** sensor models to provide a clear overview of the real-life system.

4) **Temperature:**
   - **Platinum Resistance Thermometers (PRTs)** are used for accurate temperature measurements.
   - Their design allows them to maintain **high precision and stability,** even in extreme conditions with **fluctuating temperatures**.
   - This makes PRTs ideal for applications where reliable data is crucial despite challenging conditions.
   - Industry-level PRT for GLOFs - **WIKA TR10** known for its **durability and high precision.**

5) **Sudden water flow:**
   - **Radar-based flow meters** give **accurate** measurements in harsh conditions - high turbulence & debris.
   - Their non-contact method ensures **durability** since they are mounted above the water surface, avoiding damage from debris.
   - Radar meters offer **real-time data** on both water surface velocity & level, essential for early warnings
   - Ultrasonic meters can be affected by debris & require proximity to water, increasing the risk of damage.
   - An industry-standard radar-based flow meter suitable for GLOFs is the **OTT RLS (Radar Level Sensor)**.

CHOOSING THE TYPE OF SENSOR

6) Dam Stability:

- **Strain gauges** are used to monitor dam stability by measuring **structural deformation** caused by **sudden changes in water pressure**.
- This real-time data helps identify **stress points**, providing early warnings of potential instability.
- Strain gauges are highly **sensitive**, making them crucial for ensuring dam safety under extreme GLOF conditions.
- The **Vishay Strain Gauge** is a **high-precision sensor** designed for real-time monitoring of dam stability during GLOF events.

7) Ground movement / Seismic activity

- **Moment Magnitude Scale (Mw)** is used to provides a **precise assessment** of earthquake size and energy release, which is critical for understanding potential triggers or impacts on glaciers and surrounding terrain.
- Unlike the Richter Scale, the Mw Scale offers an **accurate** representation of seismic events and **stability** over a wide range.
- **Kinemetrics K2** seismometer is an industry-level sensor used for **precise monitoring of seismic activity** and **ground movement in GLOFs**.

HARDWARE PROTOTYPE

NOTE: The implementation is still in progress. As for now, the sensor integration and the machine learning components are being developed separately.

For the basic prototype, we have used a **DHT22 sensor** connected to an **Arduino UNO** microcontroller to measure the room's temperature and humidity. This data is then logged onto a **CSV file**, which will be stored in the **cloud**. The collected data will later be used for machine learning to develop and refine the system further.

```
Humidity: 63.00%  Temperature: 31.30°C
Humidity: 62.00%  Temperature: 31.30°C
Humidity: 62.00%  Temperature: 31.30°C
Humidity: 62.00%  Temperature: 31.30°C
Humidity: 62.00%  Temperature: 31.30°C
Humidity: 61.00%  Temperature: 31.30°C
Humidity: 61.00%  Temperature: 31.30°C
```

MACHINE LEARNING FOR GLOFs

ML for GLOF Prediction:

Ensemble model combining various ML algorithms enhances accuracy:

- **Random Forest (RF)**: Utilizes decision trees to analyze historical data on glacial dam stability, water levels, and seismic shifts, capturing complex patterns and trends.
- **Gradient Boosting Machines (GBMs)**: Includes XGBoost and LightGBM, which iteratively refine predictions by correcting errors in sequential trees, improving accuracy especially with noisy data.
- **Long Short-Term Memory (LSTM)**: A type of RNN designed for time-series data, effective for monitoring real-time changes in water levels and predicting GLOF events.
- **Convolutional Neural Networks (CNs)**: Analyzes satellite imagery to detect changes in ice mass, snowmelt, or ground movement.

Stacking Ensemble Model:

- **Base Models**: RF, GBMs, LSTM, CNN, and Isolation Forest/Autoencoders for anomaly detection.
- **Meta-Model**: Uses predictions from base models to make the final prediction, often employing logistic regression or a complex model to combine inputs for improved accuracy.

Integrates different models' strengths - Handling various data types & providing a risk assessment for GLOFs

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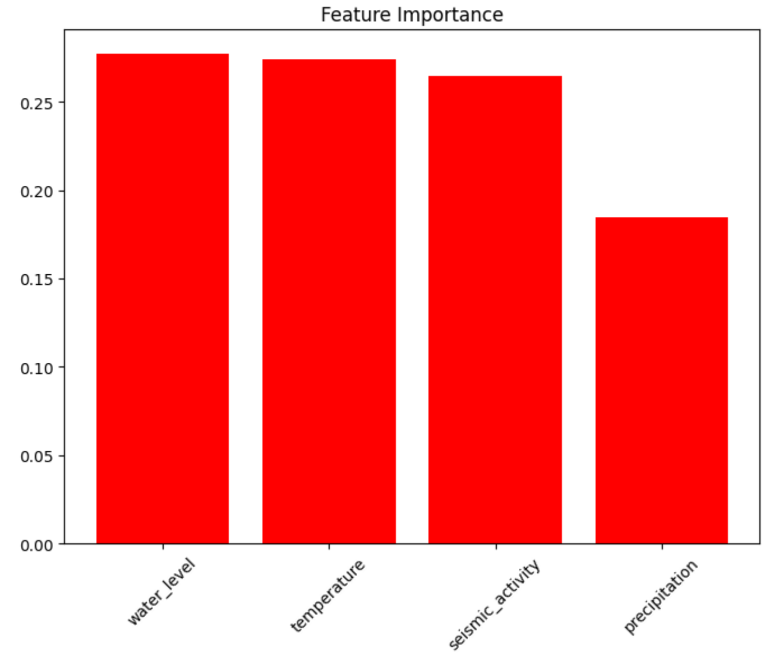
ML GRAPHS (THRESHOLDS)

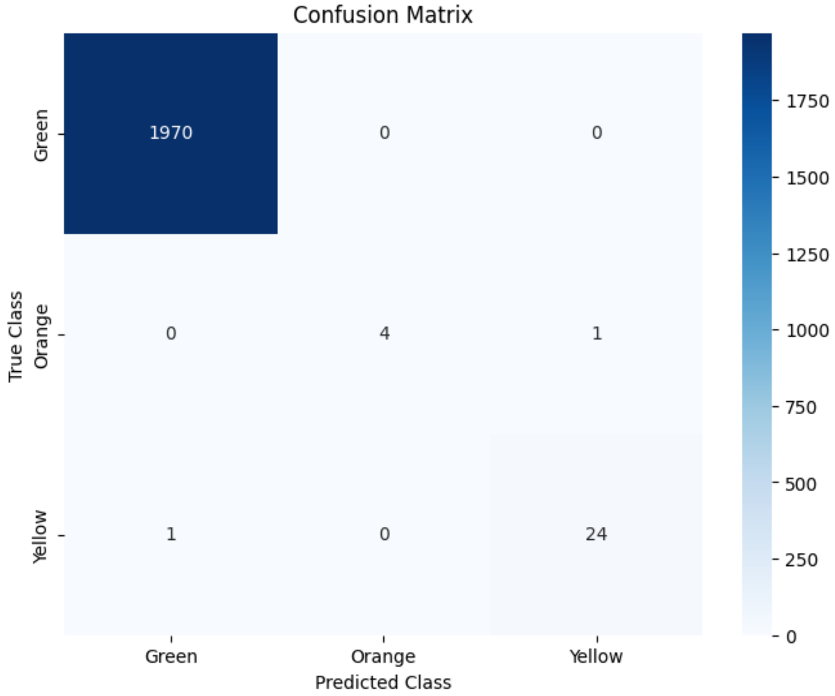
We have generated the following graphs according to our present prototype

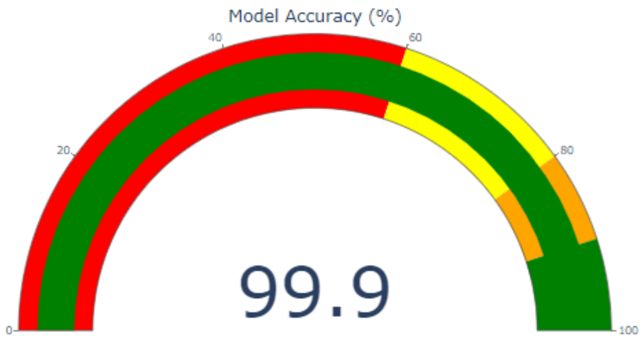
	temperature	precipitation	seismic_activity	water_level	alert_signal
0	11.236204	74.728164	7.299983	63.814457	Green
1	28.521429	66.582419	1.845120	45.929245	Green
2	21.959818	35.230783	3.466397	96.449852	Green
3	17.959755	121.453334	6.632806	21.897845	Green
4	4.680559	95.324832	4.820893	58.785642	Green

These are a few lines of **synthetic data** that have been generated for developing the ML model



Predicted Alert Signal: Orange





NOTE: The accuracy of this model is **99.9% because of using synthetic data.** With real time data, we would have lesser accuracy.

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ML GRAPHS (THRESHOLDS)

We have generated the following graphs according to our present prototype