Environmental Hazard Monitoring in Canada using Machine Learning, LLMs, and UAV Integration

ICCN LAB

Western University

May 6, 2025

1. Introduction

Canada faces increasing threats from environmental hazards including wildfires, floods, extreme weather events, and declining air quality. Such hazards significantly impact human health, the economy, and ecosystems. This research proposal outlines a comprehensive project designed to leverage advanced technologies—specifically machine learning, large language models (LLMs), and Unmanned Aerial Vehicles (UAVs) to monitor, predict, and mitigate these hazards.

2. Scope

This project will address critical environmental hazards prevalent in Canada:

- **Wildfires**: Frequent and intense forest fires, exacerbated by climate change.
- **Floods**: Regular flooding events driven by heavy rainfall and rapid snowmelt.
- **Extreme Weather**: Severe storms, heatwaves, and cold snaps.
- **Air Quality Deterioration**: Increasing levels of pollutants due to wildfires and urbanization.

3. Technical Approach

The project incorporates a multidisciplinary technical approach combining three main technological pillars:

3.1. Machine Learning Models

Advanced machine learning algorithms, including Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), and transformers, will be employed for:

- Classification of hazard severity from imagery and sensor data.

- Predictive analytics for hazard forecasting.
- Real-time anomaly detection to flag potential hazard events.

3.2. Integration of Large Language Models (LLMs)

LLMs such as GPT will analyze and interpret unstructured textual data from various sources including:

- Government-issued weather alerts.
- Emergency incident reports.
- Social media platforms.

This will enable extraction of relevant insights and automated generation of concise, actionable summaries.

3.3. UAV Data Collection and Validation

Drones will collect real-time data, providing high-resolution aerial imagery and sensor measurements including:

- Thermal imaging for fire detection and spread analysis.
- Optical imagery for flood mapping.
- Air quality sensors to assess pollutant levels in remote areas.

UAV data will validate and enhance the accuracy of predictive machine learning models.

4. Open-Source Datasets

Comprehensive use of open-source datasets specific to Ontario and Canada is integral to this project:

Dataset	**Source and Link**
Canadian National Fire Database	cwfis.cfs.nrcan.gc.ca/datamart
Ontario Forest Fire Perimeters	geohub.lio.gov.on.ca
NASA MODIS/VIIRS Fires	firms.modaps.eosdis.nasa.gov
Sentinel and Landsat Imagery	scihub.copernicus.eu, earthexplorer.usgs.gov
Weather and Climate Data	climate.weather.gc.ca
Hydrometric Data	wateroffice.ec.gc.ca
Ontario Air Quality	aqicn.org/map/ontario
Textual Hazard Reports	weather.gc.ca/warnings
Geospatial Context Data	open.canada.ca/en/open-data

Table 1: Key open-source datasets for environmental hazard monitoring in Ontario.

5. System Architecture

The system architecture comprises:

- Data ingestion from satellites, drones, ground sensors, and textual sources.
- Data processing and fusion leveraging advanced analytics.
- Visualization and decision-support interfaces.

6. Use Cases

The proposed system will support several critical use cases:

- **Real-time Wildfire Detection**: Immediate UAV deployment to validate satellite-based fire alerts.
- **Predictive Air Quality Alerts**: Integrated smoke dispersion and pollutant forecasting.
- **Flood Forecasting**: Rapid mapping and predictive analytics for early warning.

7. Expected Outcomes

Anticipated outcomes include:

- Enhanced, curated open datasets beneficial to broader research communities.
- Improved accuracy and timeliness in environmental hazard predictions.
- Significant societal impact through robust and proactive hazard management systems.

8. Challenges and Mitigation

The project acknowledges several critical challenges, addressing each through targeted strategies:

- **Data Quality**: Rigorous preprocessing, cross-validation, and augmentation.
- **UAV Operational Constraints**: Strategic drone deployment, regulatory compliance, and relay operations.
- **Complex Integration**: Multimodal data fusion and human oversight.
- **Computational Demands**: Optimal resource allocation between cloud and edge computing.

9. Conclusion

This ambitious project promises may significant advance in environmental hazard monitoring, enhancing predictive capabilities, and providing tangible benefits to emergency management and public safety in Ontario and beyond.