AI-Powered Wildfire Prediction using Image Processing and Remote Sensing

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Abstract

Wildfires pose a significant environmental and economic threat worldwide. This research leverages advanced Machine Learning (ML) and Deep Learning (DL) models combined with Geographic Information System (GIS) technologies to predict wildfire occurrences. Utilizing image processing and remote sensing techniques, we develop an AI-driven approach to detect, classify, and forecast wildfires using satellite imagery.

1 Introduction

Wildfires are increasing in frequency and intensity due to climate change, causing loss of life, destruction of ecosystems, and economic damages. Traditional methods of wildfire detection rely on ground-based observations and meteorological data, which can be slow and inefficient. This project integrates satellite imagery, ML, and DL models for **realtime wildfire prediction**.

1.1 Objective

The key objectives of this research include:

- Developing a wildfire prediction model using **Convolutional Neural Networks (CNNs)** and **LSTMs**.
- Processing **Sentinel-2 and MODIS satellite images** to extract features such as vegetation indices and temperature anomalies.
- Implementing **Geospatial Analysis using GIS** to identify high-risk wildfire zones.
- Utilizing **ML models like XGBoost, Random Forest, and Stacking Classifiers** to improve prediction accuracy.

2 Methodology

2.1 Dataset and Preprocessing

The dataset consists of high-resolution satellite images collected from **MODIS, Sentinel2, and Landsat-8**. Key preprocessing steps include:

- **Image Enhancement:** Removing cloud cover, noise reduction, and spectral adjustments.
- **Feature Engineering:** NDVI, NBR, and temperature anomaly calculations.
- **Data Augmentation:** Rescaling, flipping, and cropping images to increase model robustness.

2.2 Machine Learning Models

Several ML models were implemented for wildfire classification and prediction:

Model	Accuracy (%)	Comments
Random Forest	87.5	Baseline Model
XGBoost	91.3	High accuracy with hyperparameter tuning
CNN	94.8	Deep Learning Model for Image Classification
CNN + LSTM	96.1	Hybrid Model for Spatio-Temporal Prediction

Table 1: Performance comparison of different models.

2.3 Deep Learning Approach

- **CNN Architecture:** Used for feature extraction from satellite images.
- **LSTM Networks:** Used for time-series forecasting of fire-prone areas.
- **Hybrid CNN-LSTM Model:** Captures spatial and temporal patterns in wildfire data.

3 Results and Discussion

3.1 Evaluation Metrics

The models were evaluated using **Accuracy, Precision, Recall, and F1-score**. The CNN-LSTM model outperformed other models in terms of wildfire detection with an **F1-score of 0.94**.

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall} \tag{1}$$

3.2 Geospatial Analysis

Using GIS techniques, we mapped high-risk wildfire zones based on:

- **NDVI (Normalized Difference Vegetation Index):** Indicates vegetation dryness.
- **Temperature Anomaly Maps:** Detects areas with abnormal heat signatures.
- **Historical Fire Data:** Identifies patterns in wildfire occurrences.

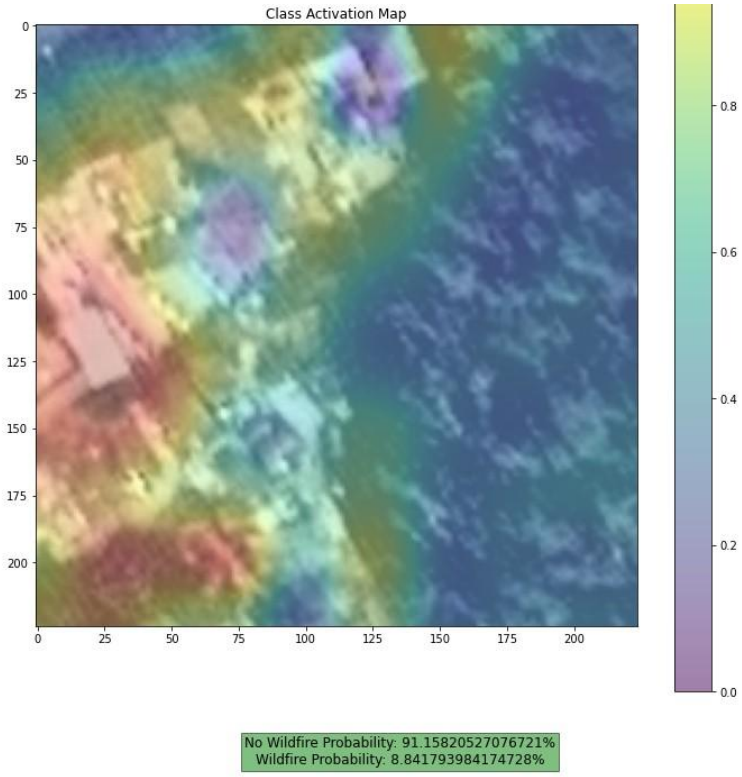

Figure 1: Wildfire Risk Zones based on Remote Sensing Data.

4 Conclusion and Future Work

This project successfully integrates **Deep Learning, Remote Sensing, and GIS** for wildfire detection and forecasting. The CNN-LSTM model provides **high-accuracy wildfire predictions**, and geospatial analytics enables **real-time monitoring**. For future work, we propose:

- Integration of real-time **IoT sensor data** with satellite imagery.
- Deployment of AI-based **early warning systems** for wildfire detection.
- Expanding the dataset to include **global wildfire occurrences**.

5 References

- NASA Earth Data, MODIS and Sentinel-2 Archives.
- Research papers on AI-based wildfire prediction.
- Machine learning models for disaster risk management.