International Journal of Creative and Open Research in Engineering and Management
ISSN: 3108-1754 (Online)
Volume 02 Issue 09 September-2026 | Impact Factor: 3.5

Hybrid Multi-Model Deep Learning for Forest Fire Prediction and Real-Time Detection: FireGuard AI

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How to Cite this Article:

Chandrika, N. M. (2026). Hybrid Multi-Model Deep Learning for Forest Fire Prediction and Real-Time Detection: FireGuard AI. International Journal of Creative and Open Research in Engineering and Management, 02(9), 1-9. https://doi.org/10.55041/ijcope.v2i9.084

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Abstract :

Forest fires are a major environmental hazard, and early prediction and detection are essential for reducing damage. To address the limitations of traditional forest surveillance in Andhra Pradesh, this project presents **FireGuard AI**, a hybrid deep learning system that combines historical weather data with live visual detection. The proposed **Hybrid Multi-Fire Model** unifies a fine-tuned **ResNet50** for real-time fire and smoke detection from webcam images and a **BiLSTM** network for district-level fire-risk prediction using weather and land-condition data from 2015–2025. The system is implemented using Flask and provides risk visualization, interactive district maps, model performance metrics, and automated **Twilio SMS alerts** for high-risk conditions. By combining predictive weather analysis with real-time image detection, FireGuard AI provides an integrated approach to early forest-fire warning and monitoring.

Keywords

Forest Fire Prediction, Real-Time Fire Detection, Deep Learning, ResNet50, BiLSTM, Hybrid Model, Weather Data, Computer Vision, Andhra Pradesh, FireGuard AI, Early Warning System, Flask

Introduction

Forest fires are a major environmental hazard that cause significant damage to forests, wildlife, and natural resources. Traditional monitoring methods in Andhra Pradesh, such as watchtowers, forest patrols, and citizen reporting, are often reactive and limited in coverage. **FireGuard AI** addresses these limitations by combining **BiLSTM-based weather risk prediction** with **ResNet50-based real-time fire detection** from webcam images. The system is implemented using Flask and provides district-wise risk visualization, interactive maps, and automated SMS alerts for high-risk conditions, enabling faster and more effective forest-fire monitoring and early warning.

Existing System

The existing forest-fire monitoring system mainly relies on **watchtowers, manual forest patrols, satellite observations, and citizen reporting**. These methods are often reactive, require significant human effort, and may not provide timely detection or accurate district-level fire-risk prediction. Weather-based prediction and image-based fire detection are generally used as separate approaches, making it difficult to obtain a unified and continuously updated warning system. Limited real-time monitoring and delayed alerts can reduce the effectiveness of early fire-response measures.

Proposed System

The proposed **FireGuard AI** system combines weather-based fire-risk prediction and real-time image detection using a hybrid deep learning approach. **BiLSTM** analyses historical weather and land-condition data to predict district-level fire risk, while **ResNet50** detects fire and smoke from live webcam images. Both models are integrated into a Flask-based application that provides risk levels, interactive district maps, performance metrics, and automated **Twilio SMS alerts** for high-risk conditions, enabling faster and more reliable forest-fire monitoring and early warning.

Objectives of the Project

The main objectives of **FireGuard AI** are to:

- Predict forest-fire risk using historical weather and land-condition data.
- Detect fire and smoke in real time using webcam images and the ResNet50 model.
- Combine weather prediction and visual detection through a hybrid deep learning approach.
- Provide district-wise fire-risk levels through an interactive map and dashboard.
- Generate timely SMS alerts when high-risk fire conditions are detected.
- Support early warning and faster response for effective forest-fire management in Andhra Pradesh.

Methodology

The methodology of **FireGuard AI** consists of data collection, preprocessing, model development, prediction, and real-time detection. Historical weather and land-condition data from the forest districts of Andhra Pradesh are preprocessed and provided as time-series sequences to a **BiLSTM model** for district-level fire-risk prediction. In parallel, fire and non-fire images are used to fine-tune a **ResNet50 model**, which analyses live webcam frames for real-time fire and smoke detection. The outputs of both models are integrated into a Flask-based application to display risk levels and interactive maps. When the predicted risk or detected fire exceeds a predefined threshold, the system generates an automated **Twilio SMS alert**, supporting timely response and early fire management.

Technologies Used

- Python – Backend Programming
- ResNet50, Computer Vision – Image Detection
- BiLSTM – Weather Prediction
- Flask – Web Framework
- Pandas, NumPy, Scikit-learn – Data processing
- Matplotlib, Folium - Visualization
- Webcam and OpenCV – Real-time Detection
- Twilio API – SMS alerts
- VS Code – Development Environment

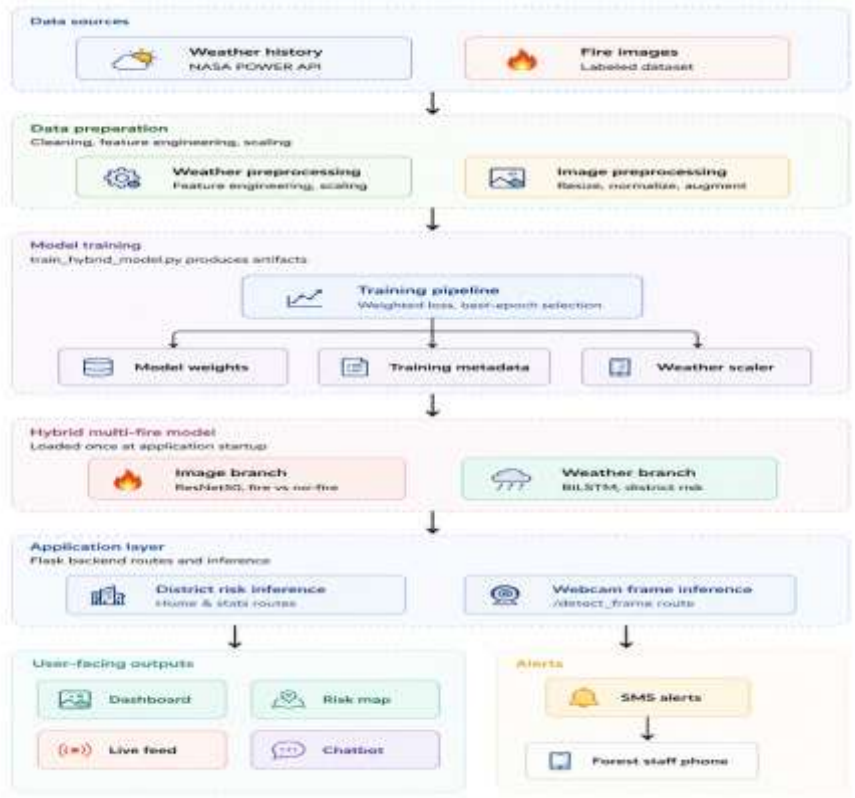
System Architecture

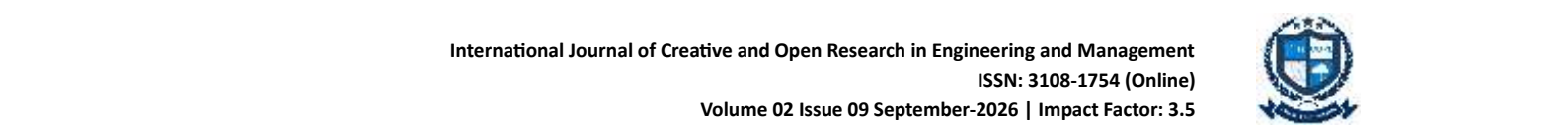
The **FireGuard AI** system follows a hybrid multi model architecture consisting of two independent prediction branches. The **weather data branch** receives historical weather and land-condition data, preprocesses the data, and uses a **BiLSTM model** to predict district-level fire risk. The **image detection branch** receives live webcam frames and uses a fine-tuned **ResNet50 model** to identify fire or smoke. The outputs from both branches are processed by the Flask application and presented through a dashboard with colour-coded risk levels, an interactive Andhra Pradesh map, and model performance information. When a high-risk condition or fire detection exceeds the predefined threshold, the system triggers an automated **Twilio SMS alert** to support rapid response.

Implementation

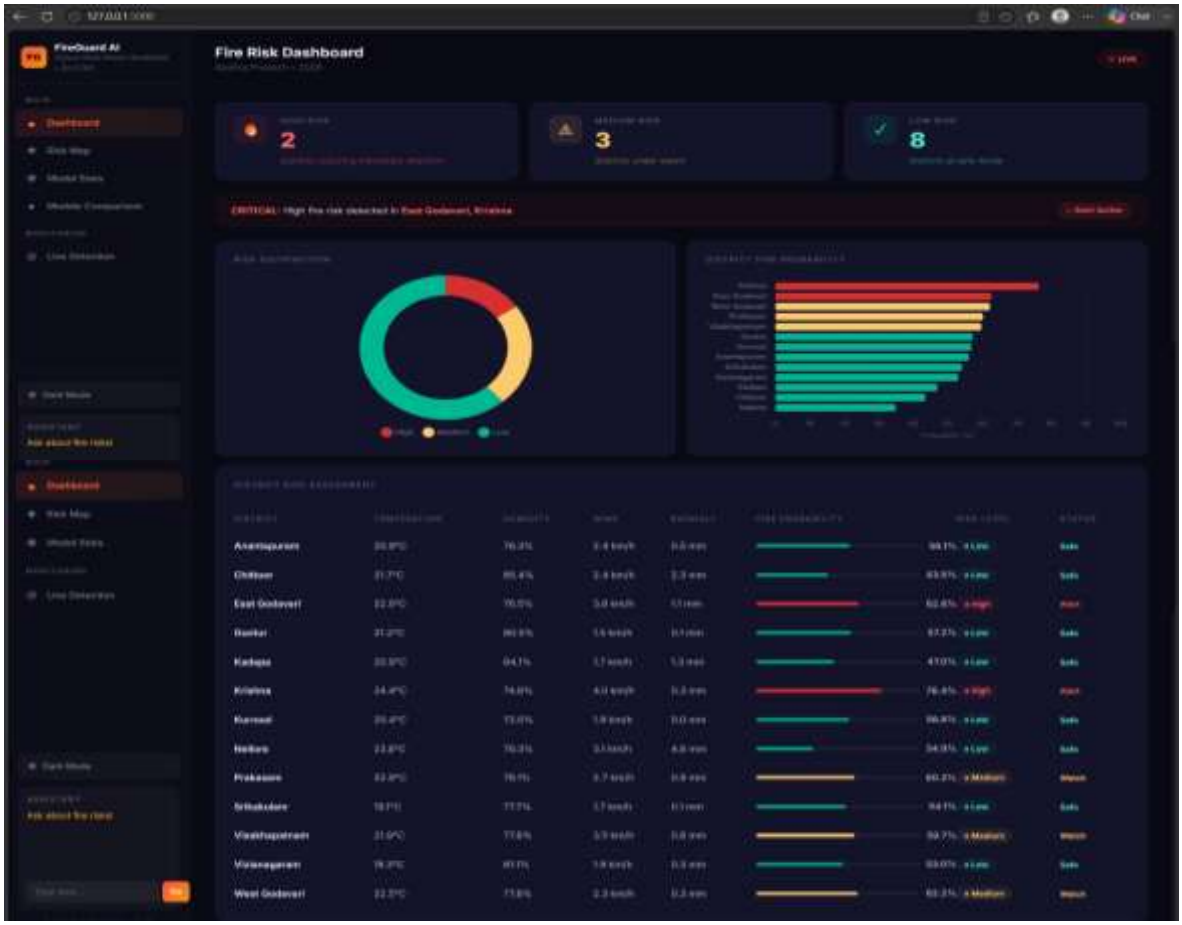
The **FireGuard AI** system is implemented using Python and Flask by integrating the trained **ResNet50** and **BiLSTM** models. The BiLSTM model processes preprocessed historical weather and land-condition data to generate district-wise fire-risk probabilities, while the ResNet50 model analyses live webcam frames to detect fire or smoke. The application displays prediction results through a dashboard and interactive Andhra Pradesh risk map with Low, Medium, and High risk levels. For high-risk conditions, an automated **Twilio SMS alert** is generated, enabling timely notification and supporting rapid forest-fire response.

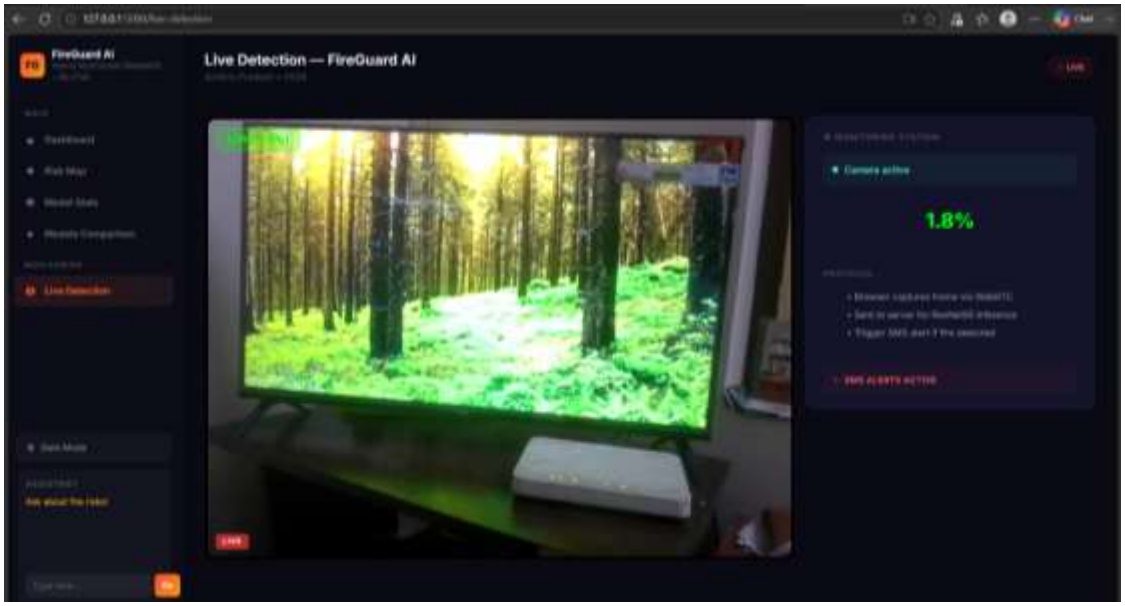
Architecture of FireGuard AI

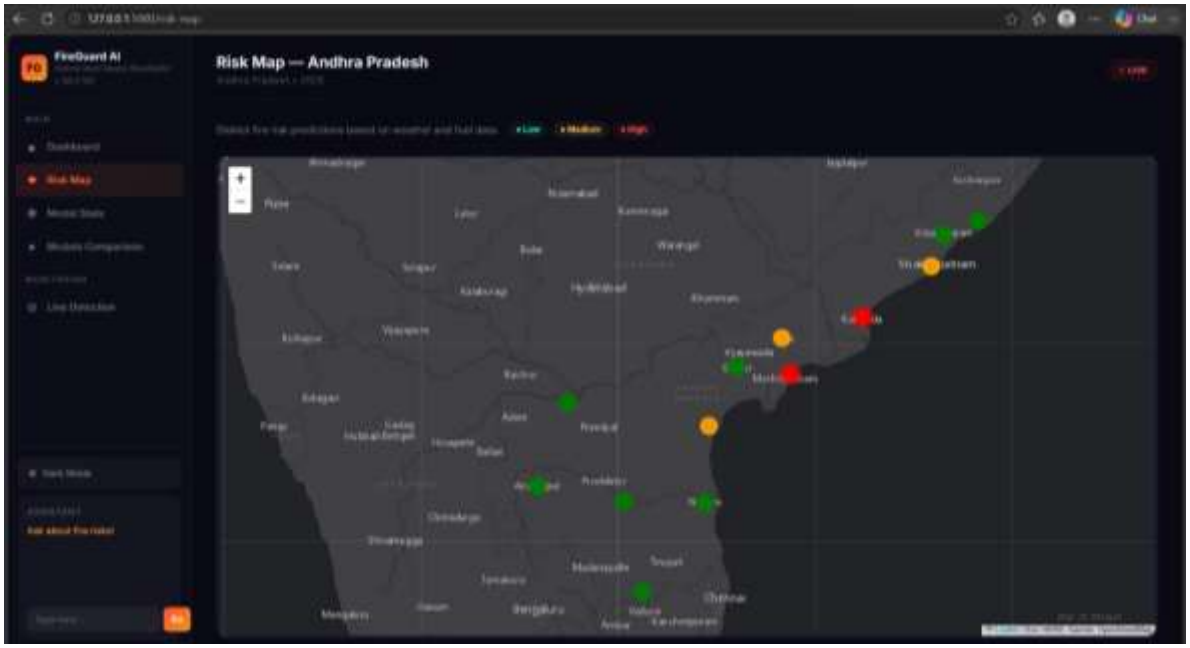


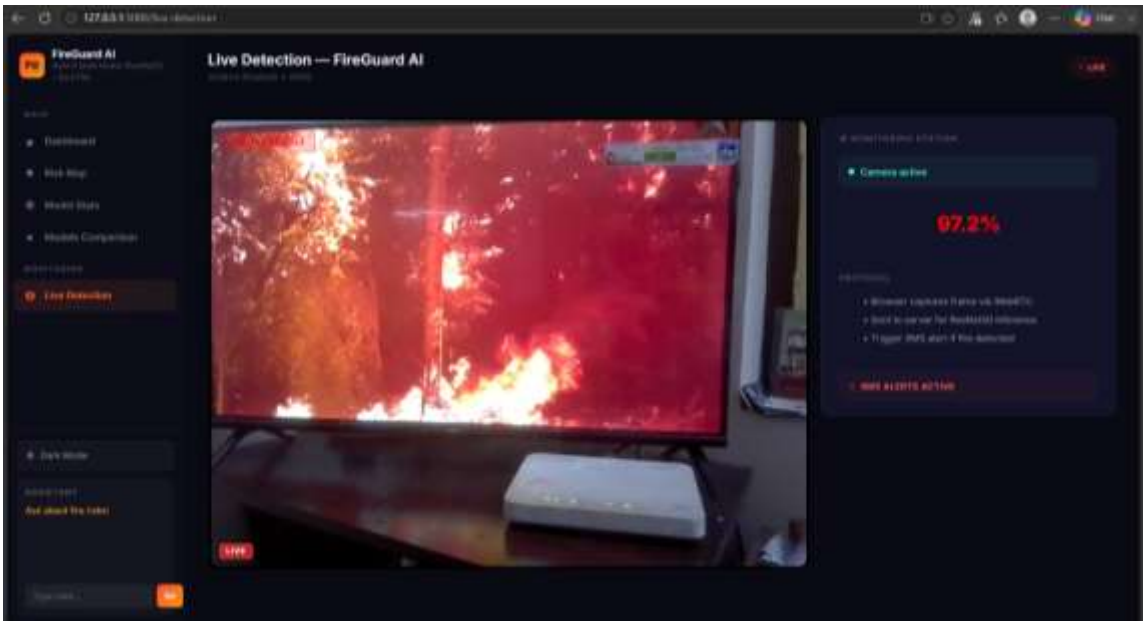


Outputs of the System :









Advantages

- Early fire-risk prediction using historical weather and land-condition data.
- Real-time fire detection through live webcam images using ResNet50..
- District-wise risk visualization through an interactive Andhra Pradesh map.
- Automated SMS alerts for high-risk conditions, enabling faster response.
- Reduced manual effort compared with traditional forest monitoring methods.
- User-friendly dashboard that presents predictions and model performance clearly.
- Scalable architecture that can be extended to additional districts and datasets.

Future Enhancements

Future enhancements of **FireGuard AI** can include integration of satellite and drone imagery for wider-area monitoring, incorporation of additional environmental and vegetation parameters, and deployment of advanced real-time models for faster and more accurate fire detection. The system can also be extended to cover more geographical regions, support

mobile applications and cloud deployment, and provide automated notifications through multiple communication channels. Continuous learning with newly collected data can further improve prediction accuracy and adaptability to changing fire patterns.

Conclusion

FireGuard AI provides an integrated approach to forest-fire monitoring by combining **BiLSTM-based fire-risk prediction** with **ResNet50-based real-time fire detection**. By analysing historical weather conditions and live visual information, the system provides district-wise risk assessment, interactive visualization, and automated SMS alerts for high-risk situations. The proposed hybrid approach reduces dependence on manual monitoring and supports faster detection, early warning, and more effective forest-fire management in Andhra Pradesh.

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