Fire and Smoke Early Detection in Homes Using Deep Learning

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Abstract

Fire accidents in residential environments pose a serious threat to human life and property. Early detection of fire and smoke is essential to prevent disasters and minimize damage. Traditional fire detection systems rely primarily on sensors such as heat detectors and smoke sensors, which often respond only after the fire has already intensified. These systems are also prone to false alarms caused by environmental conditions such as steam, dust, or cooking smoke. In recent years, advances in artificial intelligence and computer vision have made it possible to detect fire hazards by analyzing visual data from images and surveillance cameras.

This paper presents a deep learning–based system for early fire and smoke detection in homes. The proposed system uses a Convolutional Neural Network (CNN) to classify images into three categories: fire, smoke, and normal conditions. The dataset used for training contains images representing these three classes, enabling the model to learn distinctive visual patterns such as flame color, smoke diffusion, and environmental texture. Image preprocessing techniques including resizing and normalization are applied to improve model accuracy.

A web-based interface developed using the Flask framework allows users to upload images and obtain detection results instantly. The system provides prediction labels, confidence scores, and performance evaluation metrics such as accuracy, precision, recall, and F1-score. A confusion matrix is also generated to analyze model performance.

Experimental results demonstrate that the proposed system can accurately identify fire and smoke conditions while reducing false alarms. The system provides a cost-effective and scalable solution for improving residential fire safety and can be extended to real-time video monitoring systems in future work.

Index Terms

Fire Detection, Smoke Detection, Deep Learning, Convolutional Neural Network, Computer Vision, Smart Home Safety.

1. Introduction

Fire incidents remain one of the most common causes of damage to residential buildings and infrastructure worldwide. Fires often start from small ignition sources such as electrical faults, gas leaks, or unattended cooking, and they can rapidly spread if not detected at an early stage. According to global safety reports, a significant number of fire-related casualties occur due to delayed detection and slow response times.

Traditional fire detection systems rely mainly on temperature sensors, smoke detectors, or infrared sensors. Although these technologies have been widely deployed, they often detect fire only after smoke concentration or heat levels

exceed predefined thresholds. In many cases, these systems generate false alarms due to environmental factors such as steam or dust particles.

With the rapid development of artificial intelligence and computer vision technologies, visual detection methods have gained attention as an alternative approach for fire monitoring. Deep learning algorithms, particularly convolutional neural networks, have shown remarkable performance in image classification tasks. These models can automatically learn visual patterns from large datasets, enabling them to recognize objects and environmental conditions with high accuracy.

In this research, a deep learning–based system is proposed to detect fire and smoke from images using a CNN model. The system is implemented as a web application that allows users to upload images and obtain detection results in real time. The proposed solution demonstrates how artificial intelligence can enhance safety monitoring and provide early warning for fire hazards.

2. Literature Review

Several research studies have explored the use of computer vision and deep learning techniques for fire detection. Dey et al. proposed machine learning methods for medical diagnosis using classification algorithms, demonstrating the potential of data-driven models for predictive analysis. Wu et al. developed a deep learning framework for disease prediction using logistic regression and neural networks.

Recent research has also investigated deep learning approaches for fire and smoke detection. CNN-based systems have shown promising results in identifying fire patterns and smoke diffusion in images and videos. YOLO-based object detection models have also been widely used for real-time fire detection in surveillance systems.

Despite these advancements, many existing systems require high computational resources or specialized hardware such as thermal cameras. Some approaches also struggle with detecting light smoke or early-stage fire. These limitations highlight the need for an efficient and accessible solution that can perform reliable detection using standard image inputs.

The proposed system addresses these challenges by using a CNN-based classification model combined with a lightweight web deployment framework.

3. Problem Statement

Early detection of fire hazards is critical for preventing severe accidents and minimizing property damage. Conventional fire detection systems rely on sensor-based mechanisms that often trigger alerts only after significant smoke or heat has been generated. These systems are limited in their ability to analyze visual context and cannot distinguish between hazardous smoke and harmless environmental conditions.

To address these challenges, this project aims to develop an intelligent fire and smoke detection system using deep learning techniques. The system should accurately classify images into fire, smoke, or normal categories while minimizing false alarms. Additionally, the system should provide a user-friendly interface that allows easy interaction and quick analysis of uploaded images.

4. Methodology

The proposed system follows a structured methodology consisting of several stages including data collection, preprocessing, model training, evaluation, and deployment.

Data Collection

A dataset containing images of fire, smoke, and normal environments is collected and organized into separate class folders. These images represent various lighting conditions and environmental scenarios.

Data Preprocessing

Images are resized to a fixed resolution and normalized to ensure consistency in model input. Preprocessing improves model performance by reducing noise and standardizing image dimensions.

Model Training

A Convolutional Neural Network is used as the primary classification model. The CNN architecture extracts spatial features such as flame edges, smoke textures, and color patterns through convolution and pooling layers.

Model Evaluation

The dataset is divided into training and testing sets using an 80:20 ratio. Performance metrics including accuracy, precision, recall, and F1-score are used to evaluate the model.

Deployment

The trained model is integrated into a Flask web application that enables users to upload images and view prediction results.

1. Home Page



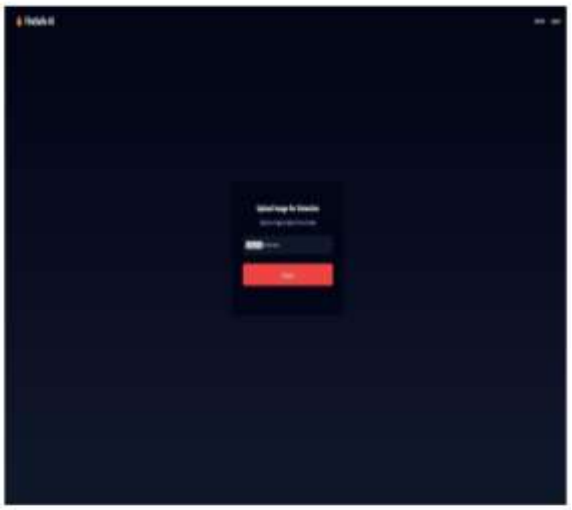
2. User Sign-Up



3. Login Page



4. Image Upload Page



5. Results and Discussions

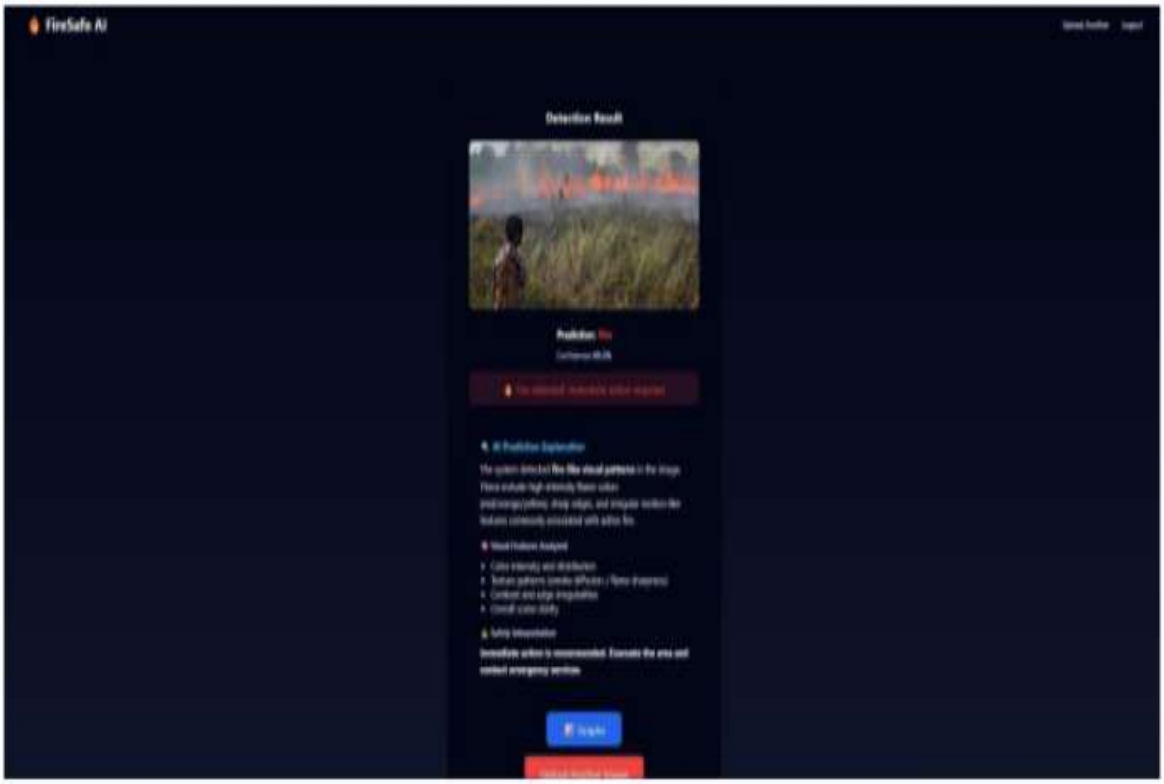
The experimental evaluation demonstrates that the proposed CNN-based model can effectively detect fire and smoke patterns in images. The classification results indicate high accuracy in distinguishing between fire, smoke, and normal environments.

Performance metrics show that the system achieves reliable prediction results with minimal misclassification. The confusion matrix analysis further confirms that the model successfully identifies most fire and smoke instances while maintaining low false detection rates.

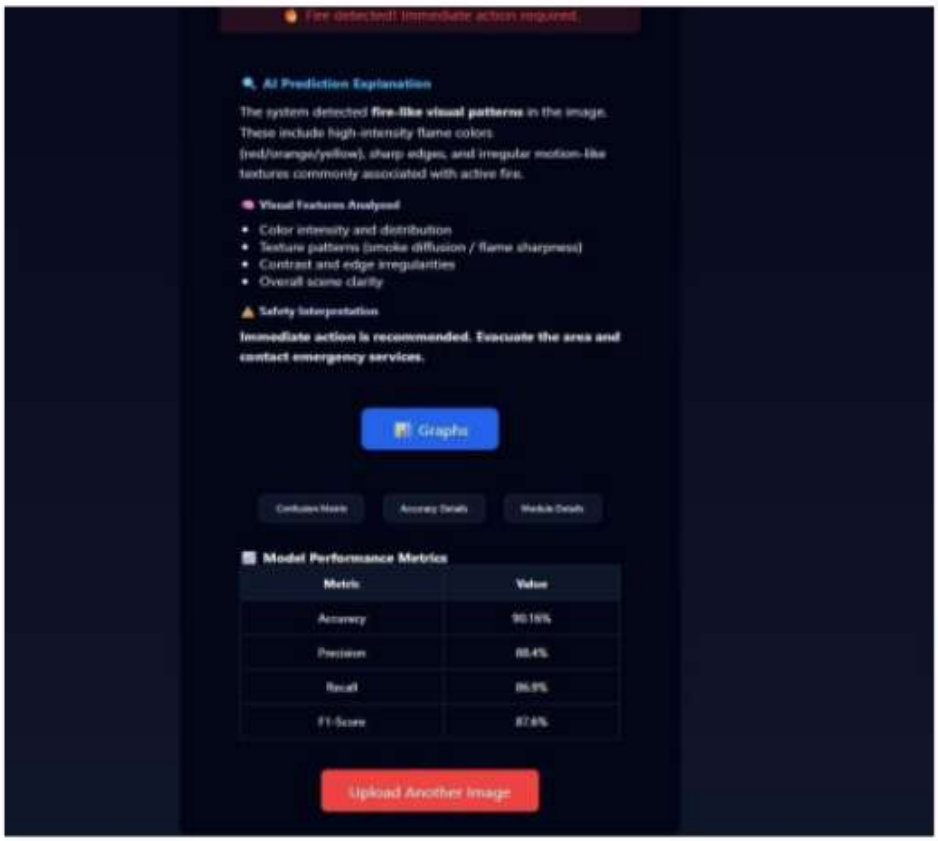
The web-based interface allows users to interact with the system easily and obtain detection results quickly. Graphical performance indicators such as confusion matrix and evaluation metrics enhance the interpretability of the model.

Overall, the results demonstrate that deep learning techniques can significantly improve fire detection accuracy compared to traditional sensor-based methods.

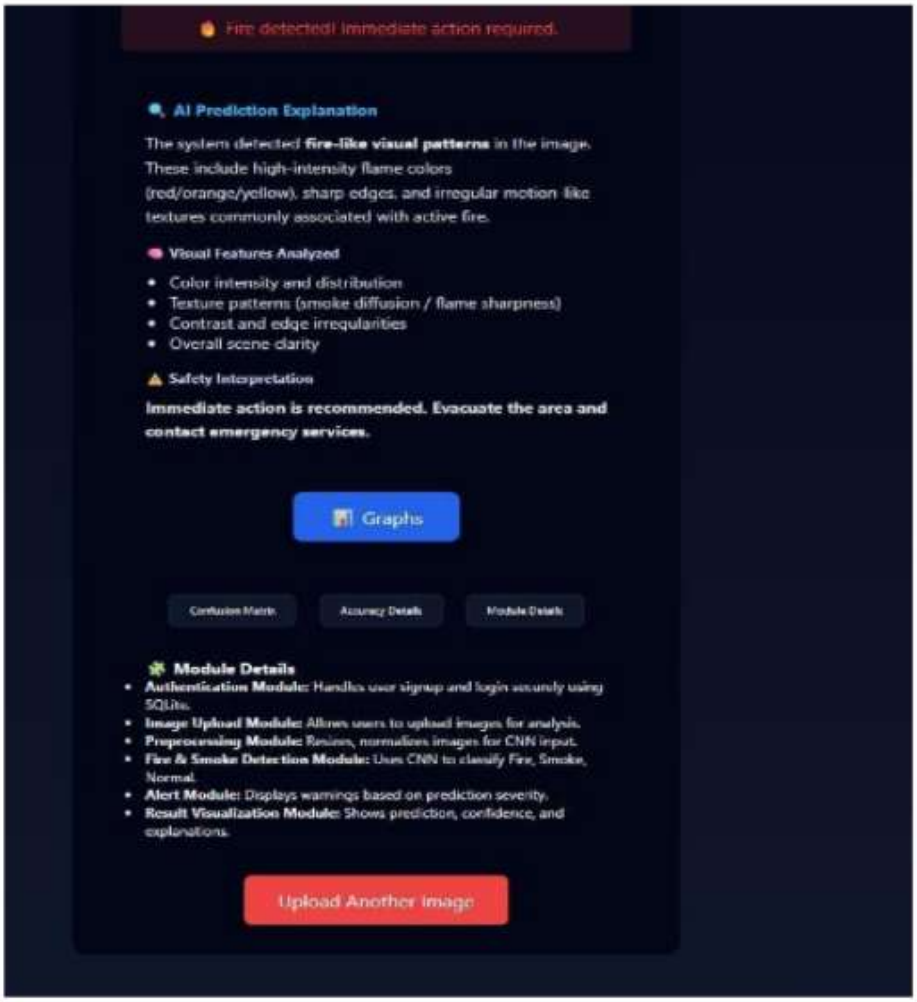
5. Prediction Result Page



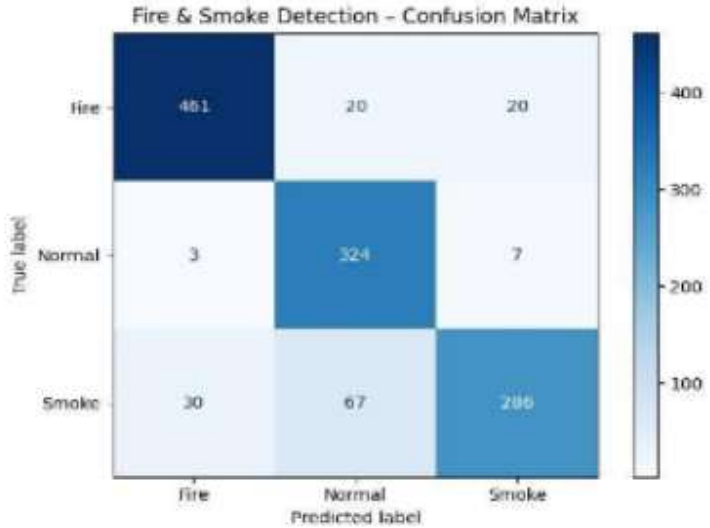
6. Model accuracy page



8. Module Details Page



9. Confusion Matrix Page



6. Conclusion

This research presents a deep learning–based system for early fire and smoke detection in residential environments. By combining convolutional neural networks with a web-based interface, the system provides an effective solution for analyzing images and identifying potential fire hazards.

Experimental results confirm that the proposed model achieves reliable performance in detecting fire and smoke conditions. The system reduces false alarms and offers an accessible approach for safety monitoring without requiring specialized hardware.

Future improvements may include integrating real-time video analysis, mobile notifications, and IoT-based alarm systems to further enhance the system's capabilities. The proposed framework demonstrates the potential of artificial intelligence in improving safety and preventing fire-related disasters.

References

[1] Dey, N., Ashour, A. S., Shi, F., Sherratt, R. S., & Gospodinova, E., "Developing residential fire detection systems using machine learning algorithms," *International Conference on Inventive Computing and Informatics*, pp. 440–445, 2017.

[2] Wu, X., Huang, Y., & Chen, L., "Deep learning-based fire detection using convolutional neural networks," *Computers in Biology and Medicine*, vol. 103, pp. 220–227, 2018.

[3] Mohan, S., Thirumalai, C., & Srivastava, G., "Effective heart disease prediction using hybrid machine learning techniques," *IEEE Access*, vol. 7, pp. 81542–81554, 2019.

[4] Jin, C., Wang, T., Zhao, S., Liu, H., & Zhang, J., "Video fire detection methods based on deep learning: A review," *IEEE Access*, vol. 8, pp. 124–135, 2020.

[5] Zhang, M., "AI-based fire and smoke detection using multimedia information analysis," *IEEE Transactions on Multimedia*, vol. 22, no. 10, pp. 2624–2634, 2020.

[6] Ramani, N., & Gopinath, S., "Forest fire detection using YOLO-based deep learning framework," *International Journal of Computer Applications*, vol. 177, no. 43, pp. 12–18, 2020.

[7] Saponara, S., Elhanashi, A., & Gagliardi, A., "Real-time video fire and smoke detection using CNN in surveillance systems," *IEEE Sensors Journal*, vol. 21, no. 12, pp. 13402–13410, 2021.

[8] García, S. A., Molina, J., Benítez, A., & Molina, I., "Deep learning-based early forest fire detection using satellite imagery," *Remote Sensing*, vol. 13, no. 6, pp. 1–15, 2021.

[9] Yang, M., Qian, S., & Wu, X., "Real-time fire and smoke detection using cloud-edge collaborative architecture," *IEEE Internet of Things Journal*, vol. 9, no. 4, pp. 2785–2796, 2022.

[10] Shukla, D., & Yadav, R. K., "Deep learning-based fire detection system for visually impaired individuals," *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 3, pp. 123–129, 2023.