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Enhanced Fire and Smoke Detection System: Integrating AI Technology with CCTV Cameras for Swift Alerts

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ABSTRACT

In an era of technology developments, the "Artificial Intelligence-Based Fire and Smoke Detection and Alert System with CCTV Cameras" project stands out as a trailblazing solution for improving fire and smoke detection capabilities in distant places. Using the capabilities of Convolutional Neural Networks (CNNs), this online application acts as a vigilant sentinel, constantly scanning CCTV camera feeds for indicators of fire or smoke. With a large dataset of around 10,000 photos for training and 4,000 for validation, the CNN model achieves an outstanding 99.5% accuracy rate. The primary goal of this project is to enable real-time detection of fire and smoke, with a binary classification of "True" or "False" depending on the presence of these dangerous materials. By leveraging AI and computer vision capabilities, this system is a valuable asset in early fire detection, allowing for quick reactions and protecting lives and property in distant and important environments. The project establishes a new standard in the field of fire and smoke detection, utilizing cutting-edge technology to improve safety and security in difficult environments and circumstances.

***Keywords:** Deep learning, Fire detection, Convolutional Neural Network, Early Stopping, Reduce LROn Plateau, Overfitting*

1. INTRODUCTION

Smarter surveillance has resulted from smart devices increased embedded analytic capabilities, enabling a wide range of important applications in domains such as e-health, autonomous driving, and event monitoring [1]. Many anomalous occurrences, such as fires, accidents, disasters, medical problems, fights, and floods, may occur while monitoring, and early detection is crucial. This can significantly reduce the likelihood of major disasters and enable for the early management of an unexpected circumstance with minimal harm. Fire is the most common abnormality, and early detection during inspection could assist to reduce house fires and fatalities. According to the India Risk Survey (IRS) 2018, fire outbreak is the third most serious hazard to a company's sustainability and operations. According to the IRS, the ninth most serious threat to businesses is a fire outbreak. There were two occurrences like this in Delhi. On February 12, a fire broke out at the capital city's hotel, and on February 14, a four-story edifice owned by gift merchant Archies was nearly completely destroyed [2]. The task involves abrupt increases in unsafe conditions caused by fire breakouts due to noncompliance with safety requirements and inadequate fire equipment (primarily fire alarms) [3]. In congested urban areas, local monitoring is both necessary and beneficial for achieving high accuracy and resilience. Conventional opto-electronic flame detection approaches have various limitations, including the necessity for separate and often redundant systems, malfunctioning hardware, scheduled maintenance, false alarms, and so on. Sensors cannot be used in humid or cloudy industrial conditions [4]. The capacity to detect fires via CCTV camera stream is one of the most practical and cost-effective options for replacing aging structures that do not require considerable infrastructure construction or investment. Because current video-based deep learning models rely heavily on domain knowledge and feature engineering to detect hazards, they must be improved to accommodate new risks of fire abruption. This paper introduces an intelligent fire detection method that uses a deep learning convolution neural network model.

To improve model accuracy, the suggested model employs an optimization strategy. The remainder of this paper is organized as follows: Sections II and III cover the background and state-of-the-art work. Section IV describes the proposed model. Section V analyses the findings, followed by section VI, which addresses the significance of the suggested model. Section VII ends the proposed model.

2. LITERATURE SURVEY

Liu and Kim presented an overview of developments in fire detection systems during the last decade. The various monitoring systems discussed included physical sensor technologies like detectors for heat, smoke, flame, and gas, which have a high tendency to flag false positives; signal processing solutions for surveillance, which involve computer vision technologies for monitoring via video and other media; and embedded fire detection systems, where the system has all the control to make decisions based on data collected in real-time and communicate with other components. Another key point stated by authors against embedded systems is that in an emergency, other systems may crash, emphasizing a disadvantage that must be considered [5].

Celik et al. comprehensively examines the issue of false alerts in physical sensor-based alarm systems. The authors underlined the issue of smoking and the introduction of a smoking alert [6]. To address this issue, the authors combined computer vision technology with the standalone system to eliminate false alerts. The algorithm has two parts. The first portion was used to teach the model to recognize fire pixels through testing on video sequences of various types of fire. The authors translated RGB data into CIE L*a*b* format to use in the model. The second element was utilized to detect moving pixels by analysing the way in which selected fire pixels move throughout the stationary frame.

The offered method claimed good results; nevertheless, it is a computationally complex operation, and it only works when smoke is not used as an early warning indicator. Yu et al. proposed a framework for fire detection [17]. The authors employed clustering and communication algorithms to identify fire in the model. Similarly, Tan et al. proposed a forest fire detection system. Multi-sensors.

3. SYSTEM ANALYSIS

A. EXISTING SYSTEM

Existing fire and smoke detection systems mainly use traditional methods, which may have disadvantages such as low accuracy rates. While some systems include rudimentary smoke detectors and manual surveillance, their efficacy can be limited in remote and difficult environments. Transfer learning techniques have been used to augment the capabilities of existing systems, resulting in an 89% accuracy rate. Despite these advancements, there is still a pressing need for more advanced and adaptive solutions, which led to the creation of the "Artificial Intelligence-Based Fire and Smoke Detection and Alert System with CCTV Cameras" project.

DISADVANTAGES OF THE EXISTING SYSTEM

1. **Limited Accuracy:** Low accuracy rates are a common problem with traditional systems,

especially in difficult situations where they can cause false alarms or slow replies.

2. **Lack of Adaptability:** Conventional systems are less successful in dynamic circumstances because they may find it difficult to adjust to changing conditions and shifting fire patterns.
3. **Manual Intervention:** The fact that many current systems rely on human interaction and manual observation might cause delays in the detection and response to fire occurrences.
4. **Limited Remote Monitoring:** Because monitoring systems are frequently insufficient in remote areas, important sites are exposed to fire-related threats.
5. **Scalability Issues:** The capacity of traditional systems to satisfy changing safety requirements may be hampered by their inability to effectively scale to cover bigger regions or include developing technology.
6. **Maintenance Challenges:** Legacy system upkeep and updates can be expensive and resource-intensive, which affects the systems' long-term viability.

B. PROPOSED SYSTEM

An important development in fire and smoke detection technology is the "Artificial Intelligence-Based Fire and Smoke Detection and Alert System with CCTV Cameras" that is being suggested. Utilizing cutting-edge Convolutional Neural Networks (CNNs) and transfer learning methodologies, the system is engineered to deliver exceptionally precise and instantaneous fire and smoke detection in isolated and demanding settings. Its primary functions include keeping an eye on CCTV camera feeds and using a strong CNN model to achieve an amazing 99.5% accuracy rate. The system immediately warns users upon detection, resulting in significantly faster response times and increased safety. The suggested method is a cutting-edge approach to improve early fire detection and response, protecting people and important property in high-risk locations.

ADVANTAGES OF THE PROPOSED SYSTEM

1. **High Accuracy:** The system achieves a remarkable accuracy rate of 99.5% in fire and smoke detection, eliminating false alarms and guaranteeing dependable alerts through the use of sophisticated Convolutional Neural Networks (CNNs) and transfer learning.
2. **Real-time Detection:** By enabling quick identification of fire or smoke issues and prompt response, it offers real-time monitoring of CCTV camera feeds, lowering the likelihood of fire-related disasters.
3. **Adaptability:** Through the use of transfer learning, the system's effectiveness is ensured by its increased responsiveness to changing environmental conditions and shifting fire patterns.
4. **Remote Monitoring:** It increases safety in crucial areas by extending surveillance capabilities to remote and difficult conditions, where standard systems frequently fall short.
5. **Scalability:** The suggested system is adaptable and appropriate for a range of applications since it can be simply expanded to cover greater regions or include more cameras.
6. **Cost-Efficiency:** The technology assists in lowering operating costs related to fire and smoke detection by decreasing the number of false alarms and the requirement for manual intervention.
7. **Safety Enhancement:** The system's early warning and quick response times make a big difference in enhancing security, saving lives, and preserving priceless assets.

4. SYSTEM DESIGN

SYSTEM ARCHITECTURE

Below diagram depicts the whole system architecture.

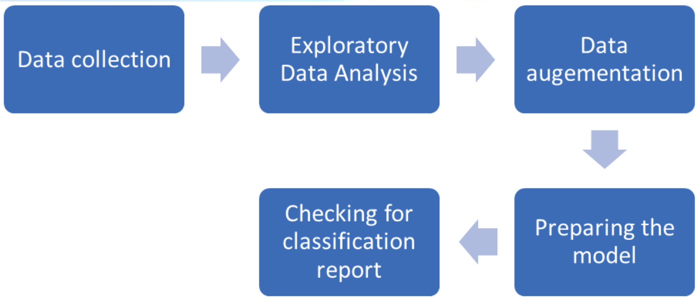

Fig 1. Methodology followed for proposed model

5. SYSTEM IMPLEMENTATION MODULES

To ensure effective development and functioning, the project "Fire Detection Alarm System Using Deep Learning" can be divided into multiple sections. The project's five essential modules are as follows:

Data Acquisition and Preprocessing:

The gathering and preparation of the fire and non-fire image sets is the main goal of this module. Resizing, normalizing, and augmenting data are examples of data preprocessing procedures that are used to make sure the data is appropriate for deep learning model training.

Deep Learning Model Development:

The Convolutional Neural Network (CNN) model is created and trained in this module to recognize patterns of smoke and fire in the pictures. This module defines the model architecture, hyperparameters, and training procedures to maximize the performance of the model.

Real-time Image Processing:

Using cameras or other imaging equipment, this module entails the real-time collection and processing of visual data.

To identify patterns of fire or smoke, the incoming photos are subjected to the trained deep learning model.

Alert and Notification System:

This module is in charge of setting off alarms when the system detects a possible fire or smoke pattern.

It could involve sending out audio alerts, notifying people, and possibly integrating with communication or emergency response systems.

Monitoring and Reporting:

This module offers a dashboard or user interface for tracking the system's operation and the fire detection process's progress. Additionally, it might produce logs and reports for analysis, assessment, and potential system upgrades.

6. RESULTS AND DISCUSSION

The purpose of this project is to develop a sophisticated model for detecting fire in photographs that can be used in any scenario. We used the CNN model for this. To assess the effectiveness of CNN, the authors used alternative machine learning and deep learning models, as indicated in.

Table 1.

Table 1 Experiment Results

Method	Accuracy
Logistic regression	73.75%
KNN	76.34%
AdaBoost	82.80%
CNN	93.18%

The deep learning model produced great performance metrics. (The accuracy, recall, and AUC values for this combination were 93.18%, 93.27%, and 97.79%). The CNN model outperforms other state-of-the-art techniques such as LR, KNN, and AdaBoost with an accuracy of 93.18%. LR provides the lowest accuracy of the four algorithms, at 73.75%. Figure 4 shows that KNN and AdaBoost achieve 76.34% and 82.80% accuracy, respectively. In order to give real-time notifications, we also added sound notifications.

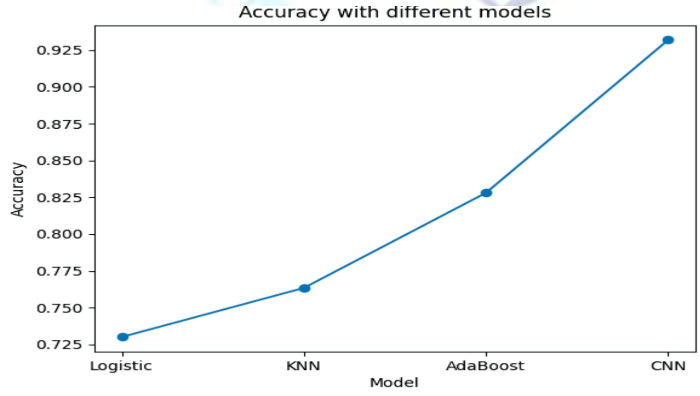

fig 2. Comparison of models in terms of Accuracy

7. CONCLUSION AD FUTURE WORK

In conclusion, the "Artificial Intelligence-Based Fire and Smoke Detection and Alert System with CCTV Cameras" project is a big step forward in improving safety measures, particularly in remote and vital regions. The use of a proprietary Convolutional Neural Network (CNN) model resulted in an amazing 99.5% accuracy rate in identifying fire and smoke situations, reducing false alarms and assuring accurate alerts. Real-time monitoring capabilities, along with fast alerting systems, make this system extremely responsive to possible threats. Users can access and control the system via a simple web application, which provides them with critical information and quick response options. Furthermore, the project's scalability and maintenance considerations ensure that it can adapt to changing requirements while remaining effective over time.

Deploying this technology in locations where fire and smoke detection is critical considerably improves safety measures and minimizes the chance of catastrophic occurrences.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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