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Enhanced Fire Alarm Systems using Deep Learning for Smoke and Fire Detection

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Abstract: Deep Learning-based fire alarm systems outperform traditional fire alarm systems in terms of life-saving capabilities. Traditionally, isolated sensors have been used to detect fires; however, they are unable to inform disaster planning teams about the size of the fire. This study addresses this issue by proposing an intelligent fire detection technology that uses pictures to detect flames and alerts the user via a 4500Hz siren for approximately 2500ms. Convolutional neural networks are employed in this study to analyse visual images. To lower the predicted output, a structured dataset comprising 3730 images of both fire and non-fire topics was used. The suggested strategy reduces the number of false alerts. This method is highly reliable. Several callbacks, including ReduceLROnPlateau and Early Stopping, increased accuracy while lowering the model's risk of overfitting. Convolutional Neural Networks outperformed AdaBoost and Linear Regression, with an accuracy of 93.08%.
Keywords: Deep learning, Fire detection, Convolutional Neural Network, Early Stopping, Reduce LR On Plateau, Over fitting

I. INTRODUCTION

Smart gadgets' rising embedded analytical capabilities have resulted in smarter surveillance and a number of useful applications in a variety of sectors, including e-health, autonomous driving, and event monitoring [1]. Many unusual events, such as fires, crashes, natural catastrophes, medical emergencies, altercations, and floods, can occur while monitoring is occurring, and early warning is critical. This can considerably lessen the likelihood of large-scale disasters while also allowing for a quick response to an unexpected scenario with minimal injury. The most common anomaly is fire, and detecting it early enough during an inspection will considerably minimize the number of house fires and fire deaths. According to the India Risk Survey (IRS) 2018, fire outbreaks are the third most serious threat to an organization's long-term stability and smooth operation. According to the IRS, fires are the ninth most serious risk to businesses. There were two instances of this in Delhi. A four-story building owned by gift shop Archies was nearly completely destroyed on February 14 after a fire broke out at the capital city hotel on February 12 [2]. The job entailed features that might quickly escalate in unsafe conditions caused by fire outbreaks, such as noncompliance with safety rules and insufficiently equipped fire gear (primarily fire alarms) [3]. To achieve high accuracy and robustness in busy metropolitan situations, detection by local monitoring is required. Many problems of traditional opto-electronic blaze detection methods include the need for separate and frequently redundant systems, malfunctioning equipment, constant maintenance, false alarms, and so on. Sensors are not suited for use in humid or foggy industrial conditions [4]. The ability to detect fires through the streaming of CCTV footage is one of the most sensible and cost-effective techniques of replacing older buildings without requiring considerable infrastructure construction or investment. Current video-based deep learning algorithms must be updated to address new fire abruption problems, as they primarily rely on domain expertise and feature engineering to detect hazards. To accomplish this purpose, this paper introduces a deep learning convolution neural network model-based intelligent fire detection system. To improve the model's accuracy, the proposed model employs the optimization technique. The rest of the document is organized as follows: Sections II and III discuss the history and ongoing research. The proposed model is discussed in Section IV. Section V covers the results, whereas Section VI discusses the significance of the proposed model. Section VII eventually concludes the suggested paradigm.

II. LITERATURE SURVEY

Liu and Kim provided an overview of advancements in fire detection systems during the last ten years. Embedded fire detection systems, which provide the system complete control over making decisions based on real-time data and communicating with other system components to raise an alarm, were among the monitoring systems studied. Physical sensor technology, such as heat, smoke, flame, and gas detectors, have a significant tendency to report false positives.

Surveillance signal processing solutions use computer vision technologies to monitor video and other media [5]. The authors also expressed concern that emergency scenarios may lead other systems to crash, which is a drawback that should be considered. Celik et al. [6] present a comprehensive investigation of the false warning problem in physical sensor-based alarm systems. The writers stressed the importance of individual smoking and raising awareness about it. The authors used computer vision technologies in conjunction with the standalone system to reduce false alarms. The used algorithm consists of two components. The initial step trained the computer to identify fire pixels by playing test films of various types of fire. The authors converted RGB data to CIE L*a*b* format for the model's implementation. To identify the moving pixels, the second section looked at the pattern in which a subset of the fire pixels traveled across the stationary frame. The suggested technique produced good results, but it is a computationally expensive procedure that is only useful when smoke is not used as an early warning indicator. Yu et al. provided a fire detection framework. The scientists used communication techniques and clustering to identify fires in their model [17]. Tan et al. also described a forest fire detecting system. To avoid erroneous warnings, multiple sensors and remote cameras were used [18]. Çetin et al. reported new advances in clip-generated fire detection [7]. Surveillance systems, including infrared surveillance cameras, can be utilized to detect fires. The writers also discussed the importance of modern video processing technologies in recognizing and investigating uncontrolled flame spread. Dampage et al. [8] described a solution to identify fire photographs that combines wireless networking sensors with machine learning models to foresee and activate the alarm when needed. This alerted the community and local fire departments to the need for fire protection. Saeed et al. [9] utilized a hybrid AdaboostMLP model to forecast fire. This model was trained using data from many sensors, including heat, gas, and smoke. Traditional machine learning algorithms were utilized to enhance computer vision technology performance.

III. SYSTEM ANALYSIS

A. *Existing System*

The authors also discussed the significance of applying modern video processing tools to detect and investigate uncontrolled flame propagation. Dampage et al. [8] developed a strategy for identifying fire photographs and informing the community and surrounding fire authorities to seek fire protection. This was accomplished by merging wireless networking sensors with machine learning models that predicted and activated the alarm when needed. Saeed et al. [9] employed a hybrid Adaboost-MLP model to predict fire. This model trained using data from a variety of sensors, including heat, gas, and smoke. The performance of computer vision technologies was improved by employing traditional machine learning approaches.

DISADVANTAGES OF THE EXISTING SYSTEM

1) *Low Accuracy:* Conventional systems usually have low accuracy rates, especially under tough settings, which can result in false alarms or delayed response times.
2) *Manual involvement:* Many of today's systems rely on human engagement and manual surveillance, which can cause delays in the detection and response to fires.
3) *Limited Remote Monitoring:* Critical locations in remote areas are vulnerable to fires due to poor monitoring techniques.
4) *Scalability issues:* Conventional systems would find it difficult to expand to cover more regions or include new technology, limiting their ability to meet changing safety needs.
5) *Maintenance Issues:* Updating and maintaining old systems can be costly and resource-intensive, compromising their long-term sustainability.

B. *Proposed System*

Compared to conventional systems, the proposed deep learning-based fire detection alarm system provides the following advantages:

Enhanced Accuracy: By employing convolutional neural networks (CNNs) to evaluate visual data, the system can identify flames and smoke patterns with more accuracy while lowering false alarms.

Advanced Data Insights: Using visual photos, the system may provide more exact information about the fire, such as its location, extent, and severity. This allows for a more successful emergency response.

Fast Alerting: The system can send out messages quickly, reducing reaction times and increasing the possibility of timely fire suppression and evacuation.

IV. SYSTEM DESIGN

SYSTEM ARCHITECTURE

Below diagram depicts the whole system architecture.

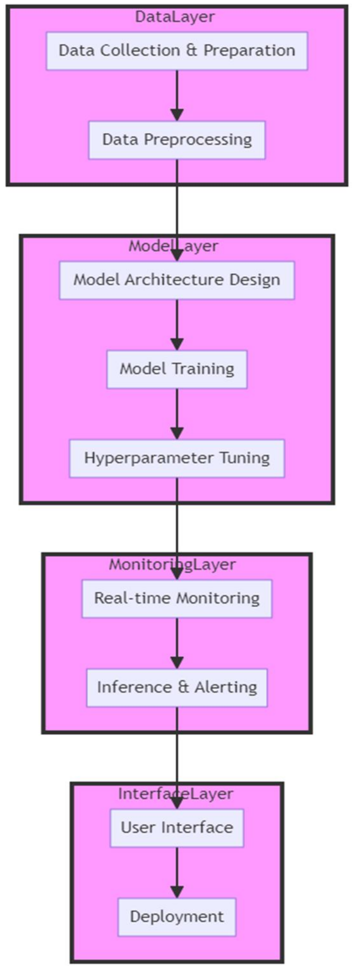


Fig 1. Methodology followed for proposed model

V. SYSTEM IMPLEMENTATION

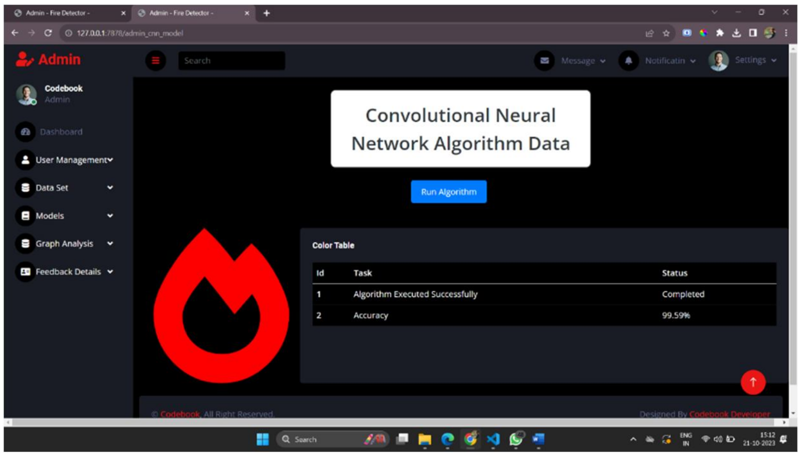
MODULES

1) *Data Collection and Preparation:* Create a big dataset containing images of smoke and fire incidents, as well as negative samples. Make sure the data is properly organized and labeled.
2) *Data Preprocessing:* To prepare the dataset for model training, perform preprocessing procedures such as augmentation, normalization, and scaling.
3) *Model Architecture Design:* Create a novel CNN architecture suitable for detecting smoke and fire. Depending on the problem's complexity, define the number of layers, filter sizes, activation functions, and pooling techniques.
4) *Train the Model:* Separate the dataset into test, validation, and training sets. Using the training data, tune the proprietary CNN model to detect smoke and fire with high accuracy.
5) *Hyperparameter Tuning:* To improve model performance, change hyperparameters like as learning rates, batch sizes, and regularization procedures.
6) *Real-time Monitoring:* Configure a web-based interface to view CCTV camera feeds in real time. Use OpenCV or similar packages to process video streams.
7) *Inference and Alerting:* Use the trained custom CNN model to make inferences about incoming video frames. Set up immediate alerts, such as alarms or email notifications, when smoke or fire is detected.

8) *User Interface:* Create a simple online application that allows users to see camera feeds, access and control the system, and get notifications.
9) *System deployment:* Install the system in remote and critical areas where smoke and fire detection is critical for public safety.

VI. RESULTS AND DISCUSSION

The deep learning model produced outstanding performance metrics. (The combination has accuracy, recall, and AUC values of 93.18%, 93.27%, and 97.79%, respectively). The CNN model exceeds other cutting-edge methods such as LR, KNN, and AdaBoost in terms of accuracy, scoring 99.59%. LR has the lowest accuracy of the four algorithms, with 73.75%. AdaBoost and KNN offer 82.80% and 76.34%, respectively.



VII. CONCLUSION AD FUTURE WORK

In order to assure early detection and reduce manual labor, the current study intended to design a classification framework that applies Deep Learning to identify fires in camera frames. Flames in CCTV cameras can be spotted with this technology. Unlike prior techniques, this does not require subject expertise or prohibitively expensive machines for innovation, nor does it necessitate highly specialized infrastructure for distribution, as hardware-based alternatives do. The capability of this system, also known as smart fire management, makes it easier to regulate fire systems and keep track of all fire safety obligations. To collect and report alarm activity to neighboring fire stations, the ideal system will incorporate the existing fire alarm panel. Installing the model on a large number of security cameras can provide benefits. Because the concept requires minimal funding, it is both technically and commercially viable. The strategy aims to create a high-growth location for this profession and lives up to the expectations.

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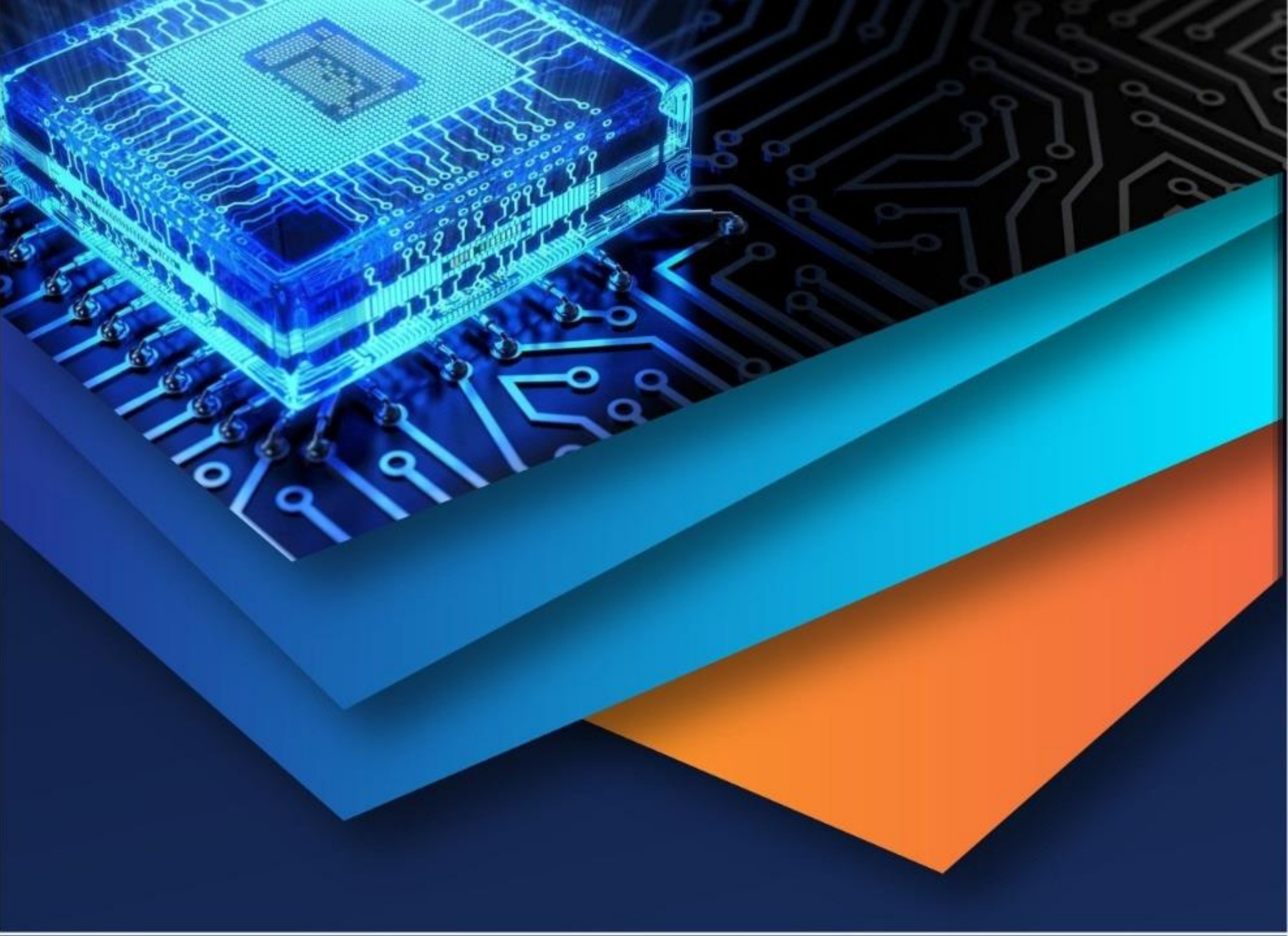

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