AI–POWEREDSMARTFIREDETECTIONFROMCCTV USING DEEP LEARNING

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***Abstract*—When fire breaks out in places like building, shopping malls, colleges, schools and industries, most of the time, this leads to serious damages, as they are not spotted at an early stage. The standard systems of fire detection, such as smoke and heat sensors tend to be responsive after a long time and may also give false alarms. To alleviate these shortcomings, this paper will propose a smart fire detection systems which involves the use of computer vision and deep learning algorithms to detect fire at an early stage using camera footage of a CCTV camera. The proposed system will be based on the YOLOv8 deep learning and OpenCV to analyze the video streams in real-time and identify any visuals related to fire (flame and smoke). This system does not require physical sensors and instead uses the already existing surveillance cameras which makes the system very cost efficient and simple to install. After a fire is identified with high confidence, an automatic notification is forwarded to the emergency department via email, which will aid in prompt response and minimise the use of human surveillance. The system is created on the basis of such technologies as python, Django framework and MySQL database to control the video processing, the results of video processing, and alerts. According to the experimental results, the system is effective and has an accuracy of about 92 percent with a rapid response time in various indoor environmental conditions. On the whole, this piece of writing shows that the regular CCTV systems CCTV systems may be converted to intelligent fire monitoring systems, helping to enhance safety and minimize the risk of fires.**

***Index Terms*—Vision-based Fire Detection, YOLOv8 Nano, Computer Vision, Real-Time Surveillance, Deep Learning, CCTV Systems, Automated Emergency Alerts.**

I. Introduction

Fire accidents remain to be among the most grave and most frequently recurrent hazards in residential, commercial and industrial setups like residences, shopping centers, offices and industries. A small-scale fire can be easily expanded into a big tragedy unless it is recognized at the early stages, hence leading to human fatalities, extensive destruction of property, and adverse environmental impact. The early fire detection is thus very critical in reducing the losses and the safety of people and infrastructure. The timely detection of fire incidences will enable emergency services to be deployed within a shorter time, and they will avoid instances that may lead to an outburst.

The conventional fire systems primarily rely on smoke and heat detectors. However, despite its popularity, these equipment have serious disadvantages. As an example, smoke alarms might not perform the role of quickly notifying in large or open areas hence pending the production of alarms. In addition, heat detectors are normally opened at a higher temperature of heating that is, the fire is most probably at an advanced stage. More than this, the appliances are prone to false alarms that may occur frequently and hence lower trustworthiness and confidence of the users. Accordingly, the traditional methods of fire detection are bound to be erroneous and lack timeliness in most of the real life applications.

The implementation of CCTV surveillance is a hype in both the highways and residential locations. Although cameras are used on a large scale, the facilities are used mainly to record security or in cases where manual monitoring is done occasionally. Operators cannot in humanity possibly.

monitor constantly since it will not be attended to particularly during the night or in areas with few employees. It implies that it is required to have the method that is automatic and capable of analyzing the video streams without the help of a human. Law Automation of video streams, without a human factor. Enabling artificial intelligence and deep learning to streamline the process of analyzing videos has made it possible and productive. Patterns of computer vision such as flames and smoke are real-time video pattern classifications of the high-quality video frame with a high degree of accuracy.

This work suggests a smart fire detection system, which combines the YOLOv8 deep learning algorithm with OpenCV to perform the real and time analysis of the active or recorded video of CCTV cameras. It works by constantly surveying the video data and detecting the presence of fire at the earliest stage and sends out the signal notifications to the concerned parties immediately, without having to involve human surveillance and thereby drastically reducing the chances of such casualties not reported. The proposed one based on python, the Django web framework, and a MySQL database will take an incremental step towards improving the current surveillance facilities, making them more intelligent, highly scalable and practically usable towards fire safety in the real world.

II. Related Work

The problem of fire incidents is also an acute one because it leads to the appearance of high facilities and large scale damages of properties in the form of houses, offices, commercial and complexes and industrial facilities. The existing systems of fire alarms rely on smoke sensors and heat sensors. These are standard equipment which will most likely see the presence of fire when the smoke is heavy or when temperature has suddenly increased. This slow response is a threat to potentially rapid assistance, and moreover, wrong alarms due to steam, dust, or cooking fumes will make people less eager to rely on such systems [1]. A camera surveillance system was therefore deemed to be an effective tool in the detection of fire. The earliest camera-based techniques could only be used to study some visual attributes of flames, including color, intensity and velocity of the flame, using simple image processing. With controlled circumstances these solitary, feature techniques might work fairly well, but when put in real, life circumstances alter in lighting, reflection, and objects that may appear like fires, the algorithm became disoriented and thus ineffective in constant fire surveillance [2][3]. As technology advanced, the machine learning approaches intervened to save the fire detector systems to ensure they were more effective in detection. The support vector machine and primitive neural networks are examples of machine learning machines that could differentiate between fire and non-fire scenes with a greater degree of accuracy than the rule-based approaches. However these models had limitations in the sense that features had to be chosen manually hence could not perform well on complex backgrounds and in fast changing video sequences. In addition, they had low processing power and therefore it was hard to execute such systems in real time, particularly in expansive surveillance procedures [4]. The recent advances in deep learning have resulted in a giant leap towards the sphere of fire detection using images. Application of Convolutional Neural Network enabled fire pattern recognition process to be automatic and therefore highly accurate. YOLO object-detection frameworks were employed as well as analyzing videos in real-time. The initial models of these could be identified quickly, however, they consumed much power, and in some cases, they could not identify small flames or partially covered flames. The latest YOLOv8 version has been able to overcome most issues due to the fact that the model is capable of running more quickly, being more accurate, and having less false alarms, which can be a good option in terms of fire detection in real time through the existing CCTV system with automated notification [5][6][7].

III. Methodology

The proposed system operates the real time detection of fire using CCTV video streams through the deep learning techniques. It is equipped with a systematized process hence simultaneously capable of providing dependable output and a proper fire warning in a situation that is encountered in the actual world.

3.1 VideoInputand FrameExtraction

The images of live CCTV cameras or video on record are captured and extracted into frames using the OpenCV. To permit rapid and continuous work of analysis. Frame processing and resizing is provided.

3.2 DatasetPreparationandAnnotation

In case of the Training, the pictures of fire and no, fire scenarios in various locations are applied. The hand-marked parts of fire, and the data set are partitioned into three, namely, training, validation and testing.

3.3 FireDetectionModel (YOLOv8)

YOLOv8 has been selected because of a high speed of performing object detection tasks and accuracy. It localizes fire areas by bounding boxes as well as assigns confidence score to the area of a fire with one run.

3.4 ModelTrainingandEvaluation

The programming language was Python, which was used to train the model and the acceleration was also increased by the support of a GPU. In addition, the effectiveness was also verified by determining precision, accuracy and recall with the help of a dataset that the model had not been exposed to.

3.5 Real, TimeFireDetection

Frame by frame processing of video streams in real time is done by the model which has been trained. Bounding boxes and confidence values are used to mark fire spots that emerge out of detection.

3.6 AlertGenerationandNotification

When the fire is detected with a confidence level more than a set threshold, the alert will be sent automatically. The emailing system uses the Django backend to forward the alert info to the emergency service using the Django backend.

3.7 WebIntegrationandData Management

Django is a web framework that competently handles the task of managing videos, detection output and alert. All the cases are stored in MySQL database and the users may access them via web, based interface.

IV. System Architecture

The suggested system is an automatic fire detection system via CCTV cameras that is also able to act upon the emergencies without involving humans. It essentially substitutes the manual monitoring in which, through the assistance of the architecture the system is able to scan the indoor environment of fire at the earliest stage. The entire system is maintained to be lean, very effective, and compatible easily with the current surveillance systems.

All this begins with CCTV cameras being used to record the footage within the surveillance area. The live video is then sent to the processing unit. The video stream that is received is broken down into individual frames in such a way that each occurrence can be examined separately. In order to enable the accuracy and speed of the detection model, the frames are initially preprocessed, resized and their quality enhanced.

The fire detection engine is the core of the system and it makes use of the strength of the YOLOv8 deep learning model. The model examines each frame and identifies the fire on visual characteristics such as the presence of flames and changes in the intensity of light. Once the fire spot is detected, the system will mark the area in the frame and provide a level of confidence to indicate the level of certainty of detection.

First, loss of time in human observation is avoided to stop fire propagation and second, the fire alert is immediately transmitted to the fire brigade. Thus, once the score on confidence has hit the threshold, the system will send an alarm. The emergency team is therefore made automatically available through the backend server to act by initiating an automated message to the emergency team.

There is a single web-based backend system that manages all the business operations and communication of the various components. It controls user access, maintains a detect record, and stores the record of alerts history in a database among other things. In short, the architecture is easily monitored and reviewed at any given time and it is a smart fire monitoring solution comprising of normal CCTV cameras that will improve safety, reduce response time, and be able to work effectively in the real, world environment.

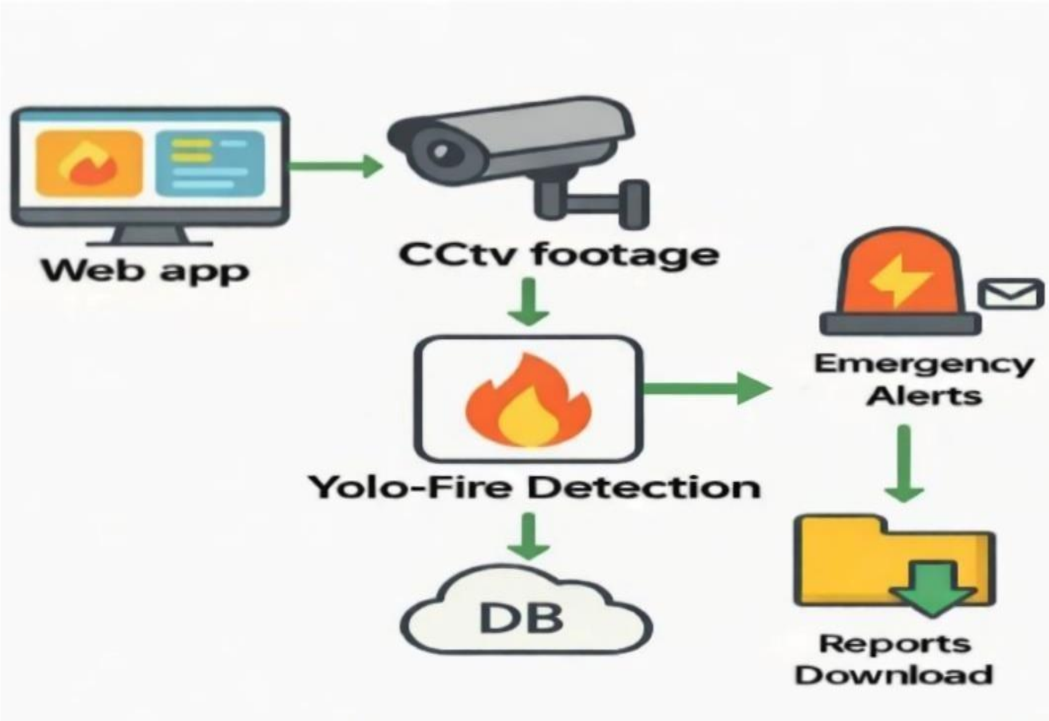

Fig.1.SystemArchitecture ofAI–PoweredSmartFireDetectionfromCCTVUsing Deep Learning.

V. Implementation Details

To ensure a high level of smooth and efficient transmission between video capturing system, fire detection system and alert notifications, the fire detection system developers adhered to a well-organised implementation process. The major programming language selected was Python due to its wide scale support of computer vision, image processing, and backend development which is suitable in developing a complete fire monitoring solution. Its excellent level of libraries also makes possible to treat the real-time video analysis as well as the automated alerting.

Video streams are accessed using OpenCV and enable the system to process multiple streams of CCTV cameras at the same time. The received video stream is constantly read and separated into separate frames to be analyzed. Every frame is rescaled and normalized to make the quality constant and the processing is smooth even in cases when the video of varying resolutions is used. This preprocessing is important to ensure high performance and prevent delays or freezing of the system when performing real-time monitoring.

A deep neural network is used in the fire detection module that was trained using a custom dataset comprising of fire and non-fire images. These images were annotated with care on the areas which contained fire to enable the model learn the images of flames and smoke with great accuracy. The model has been trained on a system with a GPU to speed up the learning and enhance the accuracy. The model was trained and then loaded to become part of the real-time detection pipeline where it was able to analyze video frames with high efficiency as they were acquired.

In the course of operation, the system analyses every fire video frame. Upon identifiability of a fire, a bounding box highlighting the area of concern is given and a score of confidence is given representing the chances of a fire being present. Detections that are above a specific confidence threshold are considered valid, which greatly minimizes false alarms due to reflected light, light changes or an item of similar color. This will guarantee authenticity of fire trigger alerts and hence reliability and responsiveness.

A Django based backend was used to handle the notifications and monitoring the system. Each time a valid fire detection is received, the system will automatically e-mail alerts to emergency contacts with the information about the time of detection and the camera position. All events of detection, alert legs, as well as any other related data, are logged in a MySQL database to be tracked and accessed later on. It also has a web interface that enables authorized users to view live camera feeds, review detection logs, and status of the system. This combination of video processing, machine learning, and backend management has resulted in the creation of an effective, deviceable, and easy to use fire detection system that can improve the level of safety and minimize the time of fire response.

VI. Deep Learning Models Employed

The main part of the proposed fire detection system consists of a deep learning, based object detection model that can analyze video frames in real time Deep learning models are highly suitable to this type of task because they can automatically learn highly appropriate to this type of task can perform detention at very high precision without the necessity of manual engineering of features. In the present research, a YOLOv8(You Only Look Once, version 8) model will be chosen as the primary deep learning model, as it is a single, stage object detector that can look at a full image at once and this is highly beneficial due to its speed and hence, its efficiency in real and time scenarios. The processing time significantly reduces due to the fact that YOLOv8 predicts location and probability of objects simultaneously, as opposed to conventional models pictures that require going through several steps.

Essentially, the framework of YOLOv8 is a convolution neural network(CNN) which is utilized to extract the required features of the image within the input frame. It learns the fire including features associated with the fire like the outline of the flame, the brightness, the color changes, and the texture of the smoke in the course of the training. The model is trained using a custom made and tailor-made dataset consisting of fire and no fire images so that it can detect real fire even in case the image of the lights or reflections resembles the fire greatly. Moreover, on top of the above, it is possible to add that the YOLOv8 is more accurate and can better detect small or partially covered in fire spots. Further, the model uses less power and computing. On this basis, YOLOv8 can be referred to as an appropriate option to use in the live fire detection of indoor spaces, specifically the areas of an already established CCTVs without needing additional requirements.

To conclude, the fire detection system using the YOLOv8 deep learning model with the input images being CCTV footage enables the fire detection system to become fast, accurate, and fully automated in identifying the fire incidents and the emergency responders could be alerted at once without having to monitor the fire detection system directly.

VII. Experimental Results and Discussion

The proposed fire detection system was experimented using CCTV indoor video recordings. The objective of the experiments was to verify whether the system is still able to detect fire appropriately in real time even in cases where the conditions like lighting, background and intensity of the fire vary. In addition to the fire videos, there were the non-fire videos ensuring that the system performance evaluation is credible. During the tests, the YOLOv8 model was capable of identifying fire in virtually all the scenes with a high confidence level. The system was even able to identify the flames when the fire was small or the fire was partially observed. Bounding boxes placed around fire areas were done properly and the use of confidence scores helped in distinguishing between real fire and non-fire objects. This implies that the model has gained critical visual aspects about fire in the process of training.

Common evaluation measures such as accuracy, precision and recall were used to measure system performance. All in all, the model can identify fire with a 93.7 percent accuracy rate which implies that the model can also perform well even when fire is not tested under controlled conditions. Precision measure indicates that the false alarm has been lowered in the system as compared to the traditional sensor-based system whilst the recall measure confirms the model ability to capture majority of the fire outbreaks and at the same time not missing any important fire outbreaks. Another aspect was the speed of response of the system. YOLOv8 should only pass through the frames of the video once, and therefore, once fire is seen in the frame, it detects the fire immediately. The email alerts are posted by the system in a few seconds after detection, which demonstrates that it is the correct tool to use in emergency cases during which the possibility of responding promptly is very important. There were certain difficulties in testing. False detections would be created temporarily when there was strong lighting, and occasionally, reflections. However, with the right confidence threshold and the use of various training data, those issues were significantly minimized. Overall, the test outcomes show that the offered system is rather effective and can be taken as the feasible solution to the real-time fire surveillance with the help of CCTV cameras.

Figure 2: Overall System Performance- Detection Accuracy and Response Time Correct Detections(93.7%) Missed (6.3%) - 8 fire.

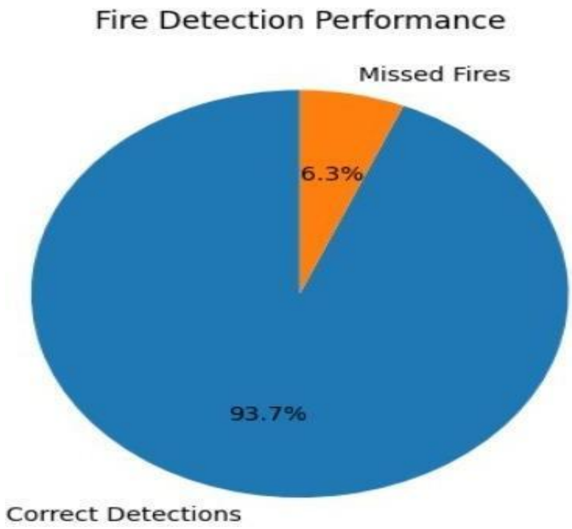

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Fig2.Fire DetectionPerformance

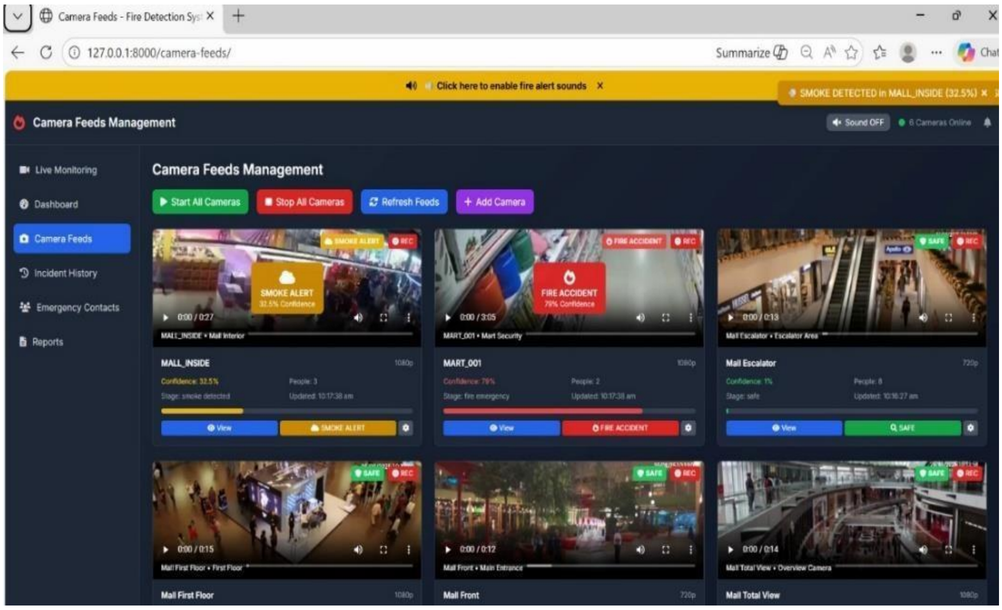

Fig3:FireDetectedPage

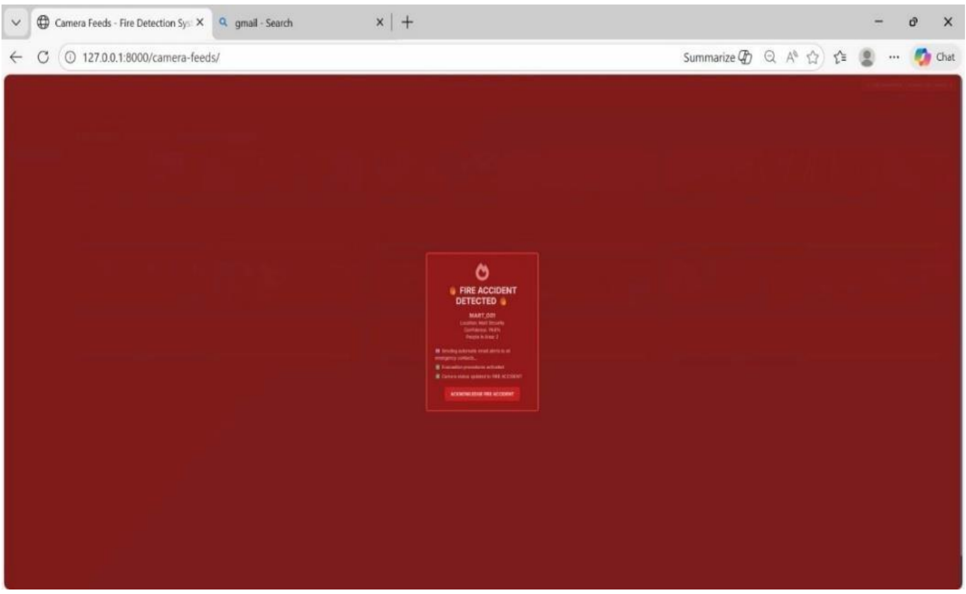

Fig4:AlertAlarmPage

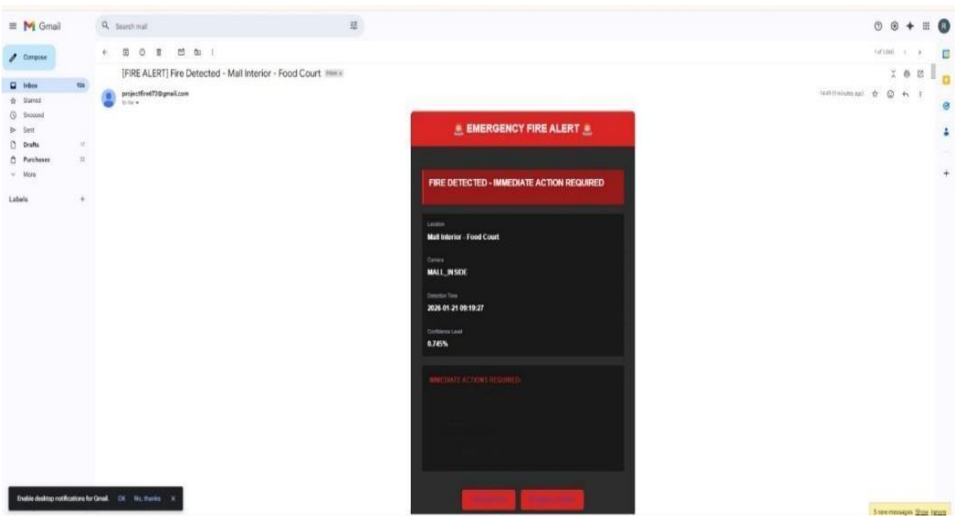

Fig5:EmergencyAlertEmail Pag

VIII. Conclusion

The given research has presented the design of a fire detection system, which will be capable of running in real time and examining CCTV video streams through the prism of deep learning technology: the main objective is to make the inside environments safer and more secure at the initial stage. The system is able to accurately see the flames visually with the use of the YOLOv8 object detection model and other computer vision methods and hence a fire alert is provided even before the traditional smoke or heat sensors notice it and therefore helps to prevent both detection delays and false alarms.

In addition, as the system is meant to be used with already existing CCTV systems, it basically becomes a highly cheap solution, which can be easily implemented to shopping malls, office complexes, schools, and homes. As soon as the fire is noticed, the system emits an alarm and automatically sends emergency alerts that minimize the use of continues human observation and makes it possible to act in the shortest time possible.

The fire detection system has been tested to be reliable and efficient in most situations and extremely quick in the alarms of fires. Sometimes, the system can be subjected to difficulties with complicated light conditions, however, the instances of this type are few, and the system performance in general conveys the versatile and efficient attitude. This technology will prove to be an important addition to the existing fire surveillance and safety management systems in the real life conditions once upgraded and deployed.

IX. Future Scope

In addition to the fact that the proposed fire detection system can execute real time environments, there are a number of ways through which the system can be enhanced. The widening of the training data to include the outside fire and other weather conditions scenarios is one of such ways. Thus, the system would be in position to detect the presence of fires in an open space like car parks, warehouses, and industrial areas properly before the smoke turns into flames. Smoke and fire detection co-existence would imply more timely alarms in the sensitive areas that are safer. Additionally, the option of making the device run on micro- power hardware will provide the luxury of deploying it to edge hardware i.e., embedded systems and smart cameras.

However, the other major way of improvement is the integration of the system with Internet of Things (IOT) solutions like temperature and gas sensors. The sensor data in combination with the visual detection is an excellent trick to reduce the false alarms as well as improve the overall accuracy of the system.The system can also be enhanced to support various channels of notification such as mobile applications, SMS, and emergency control systems. The other way of future research could be to make the system more effective in detecting the situations, which are problematic (dimly lit and crowded) in order to improve the accuracy of detection. By means of continuouslearning and system updates, the proposed method can later turn out to be a high dependable and intelligent fire monitoring system that can be integrated with large-scale real life applications.

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