Fire Detection System

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ABSTRACT
Fire plays a major role in providing light but it is dangerous as itspreads rapidly. This paper deals with the monitoring of fire using drones and cameras by applying image processing. Image processing is a type of processing in which input images are transformed into another image as output with certain techniquesapplied to it. The drone camera records the video and the recorded video is uploaded and fire is detected. This is done by using the HAAR cascade classifier algorithm. The HAAR cascade classifier, a popular object detection algorithm, is employed to identify flames in drone footage. OpenCV, a powerful open-source computer vision library, is utilized for image processing and analysis. The captured footage is then processed, and the HAAR classifier is applied to detect fire and smoke regions within the frames. To enhance the system's efficiency, various image processing techniques are implemented, such as image filtering, thresholding, and region ofinterest (ROI) extraction. Additionally, measures are taken to handle challenges like dynamic lighting conditions and false positive detections. The system generates alerts and notificationswhenever a fire is detected, enabling prompt action by authoritiesor firefighting teams. Once a fire is detected the system could send an alarm and send a notification to the user's mobile devicevia GSM.

Keywords
Fire, Camera, Drone, Image processing, HAAR-Cascade.

1. INTRODUCTION
Fire detection is a crucial task for people's safety. To prevent damages caused by fire, several fire detection system have been developed. Most of these systems are based on sensors, and they are generally limited to indoor use. If the sensors are damaged or poorly configured, they can cause heavy casualties in case of a real fire. These methods have a fatal flaw in that they only work under certain conditions. To get over such limitations, video fire detection systems are used to detect particles using ionization. There is a noticeable inclination to use conventional fire detection methods with computer vision-based systems due to the quick advancements in digital cameras and video processing techniques. Traditional fire protection techniques include mechanical or human observers to keep an eye on the environment. The most popular methods for detecting fire smoke often rely on air transparency testing, temperature monitoring, and particle sampling. Before the particles get tothe sensors and turn them on, no warning is raised.Networks of Wireless Sensors The demand for regular distribution of sensors nearby proximity makes coverage of broad regions ina forest problematic for a wireless sensor-based fire detection system. Additionally, battery charge is a significant obstacle.

2. RELATED WORK
Punam Patel, et.al., (2016) proposed a paperentitled Flame Detection using Image ProcessingTechniques. Proposed that image-based fire detection needs several sequential frames from the original video, which consists of fire and non-fire images. It consists of three main stages fire pixel detection using RGB and YCbCr color models, moving pixel detection, and analyzing the shape of fire-colored pixels in frames. This method is applied to video sequences and then fire is detected[1].

Jareerat Seebamrungsat, (2014) proposed apaper entitled Fire Detection in the Buildings UsingImage Processing. Proposed the use of the Colour Segmentation technique to segment fire from itsbackground. The properties of the HSV and YCbCr color models are used to separate the flame colors from the background. The HSV color model is used to detect information related to color and brightness. Then, they calculate the number of white frames by the difference between the previous frames and the actual frame for five frames consecutively[2].

Khan Muhammad, et.al., (2018) proposed a paper entitled Efficient deep CNN-based fire detection system and localization in the video surveillance system. This system proposed the intelligent feature map selection algorithm is proposed for choosing appropriate feature maps from the convolutional layersof the trained CNN, which are sensitive tofire regions. These feature maps allow a more accurate segmentation of fire compared to other handcrafted methods. Using this the size of the model was reduced from 238 MB to 3 MB, thus minimizing the cost and making its implementation.Another feature of this system is the ability to identify the object which is on fire, using a pre-trained model[3].

Abdulaziz, et.al., (2018) proposed a paper entitled An Efficient Deep Learning Algorithm for Fire and Smoke Detection with Limited Data. Proposed a convolutional neural network and created a newsmall of fire and smoke images to train and evaluate the model to solve the overfitting problemin training the network on a limited dataset, they improve the number of available training images using traditional data augmentation techniques.They collected a new dataset, which consists of fire, and smoke images dataset that can be used to train the network and test the data and this helps thenetwork to learn fire and smoke features under different weather and light conditions[4].

Qingjie Zhang, et.al., (2016) proposed a paper entitled Deep Convolutional Neural Networks for Forest Fire Detection in the International Forum on Management, Education and Information Technology Application by Aviation University of Air Force, Changchun. They use a small subset for developing and evaluating the algorithm. In this work, they investigated two types of classifiers: a linear classifier and a non-linear one due to the size of our annotated dataset being small. They changed the number of outputs in the last fully connected layer into two for our binary classification. In this network, they also reduced overfitting these are trained in just several hundred iterations and reach both training and testing accuracy as high which is surprisingly good[5].

Sebastien Frizzi1, et.al., (2017) proposed a paper entitled Convolutional Neural Network for Video Fire and Smoke Detection in IEEE Transactions. The main objective of their classification is to decide whether an image contains fire or smoke. They created three subsets of training 60% of images, Validation 20%, and testing 20%. To optimize the detection and localization of fire on a video, we must improve our training set. The training data hasbeen realized with a computer composed of a microprocessor Intel Xeon (frequency CPU 3,1Ghz, RAM 16Go) and a graphic card GTX 980 Ti 2816 cores, 6 GB memories).In addition to that, they compare the algorithm to conventional methods over a wider variety of video fire images like different materials, sources, and ventilations the classification accuracy on the test set[6].

Surapong Surit, Watchara Chatwiriya proposed a method to detect fire by smoke detection in video. This approach is based on digital image processing approach with static and dynamic characteristic analysis. The proposed method is composed of following steps, the first is to detect the area of change in the current input frame in comparison with the background image, the second step is to locate regions of interest (ROIs) by connected component algorithm, the area of ROI is calculated by convex hull algorithm and segments the area of change from image, the third step is to calculate static and dynamic characteristics, using this result we decide whether the object detected is the smoke or not. The result shows that this method accurately detects fire smoke. [7]

P. Piccinini, S. Calderara, and R. Cucchiara proposed a method based on the wavelet model and a color model of the smoke. The proposed method exploits two features: the variation of energy in wavelet model and a color model of the smoke. Smoke is detected based on the decrease of energy ratio in wavelet domain between background and current. The deviation of the current pixel color is measured by the color model. Bayesian classifier is used to combine these two features to detect smoke.[8]

R.Gonzalez proposed a method to detect fire based on Wavelet Transform. Stationary Wavelet Transform is used to detect Region of Interest. This method involves three steps preprocessing, SWT, histogram analysis. In preprocessing unwanted distortions are removed and image is resized and transformation of resized image is performed. High frequencies of an image are eliminated using SWT and the reconstruction of image is done by inverse SWT. Image indexation is performed to group the intensity colors that are closed to each other. Histogram analysis is used to determine the various levels of indexation. After analysis a comparison is made with non-smoke frame and non-smoke images are eliminated. These three are combined and fire is detected. [9]

Osman Gunay and Habiboglu proposed a system based on Covariance Descriptors, Color Models, and SVM Classifier. This system uses video data. Spatio-temporal Covariance Matrix (2011) is used in this system which divides the video data into temporal blocks and computes covariance features. The fire is detected using this feature. SVM Classifier is used to filer fire and fire-like regions. This system supports only for clear data not for blur data. [10]

Dimitropoulos (2015) proposed an algorithm where a computer vision approach for fire-flame detection is used to detect fire at an early stage. Initially, background subtraction and color analysis is used to define candidate fire regions in a frame and this approach is a non-parametric model. Following this, the fire behavior is modeled by employing various Spatio-temporal features such as color probability, flickering, spatial and spatiotemporal energy. After flame modeling the dynamic texture analysis is applied in each candidate region using Linear Dynamical Systems, Histogram and Mediods. LDS is used to increase the robustness of the algorithm by analyzing temporal evolution of pixel intensities. Pre-processing is done after this to filter non-candidate regions. Spatio-temporal analysis is done to increase the reliability of the algorithm. The consistency of each candidate fire region is estimated to determine the existence of fire in neighboring blocks from the current and previous video frames. Finally, a two-class SVM classifier is used to classify the fire and no fire regions. [11]

Hamed Adab proposed another system which is based on Indexing. GIS techniques and remote sensing provides further assistance. The indexing may be structural fire index, Fire risk index, Hybrid fire index. Depending on the geographical condition of the area the indexing differs. Validations of indices are based on hot spot data. Structural fire indices show static information and it does not change over short time span and used to predict the risk in advance. Fire risk index changes as the vegetation or climate changes. Hybrid index is a combination of Structure and Fire index. The disadvantage of this indexing is that way of combining. [12]

Akshata & Bhosale proposed another method where Local Binary Pattern acts as a base for fire detection and Wavelet Decomposition is used to detect fire. Pixel level analysis is required in this method. This method uses YCbCr color model to detect fire. Detection is based on three phase. The first phase involves segmentation of image using LBP. LBP is a texture operator whose value is computed using image's center and neighboring pixel values. Further accuracy is improved using Wavelet Transform and complicated data is classified using this approach. 2D Discrete Wavelet Transform is used for decomposition in this system. 2 images should be used as input and the sub bands of every image are compared with the other, if sub bands are equal the images are same else different.[13]

Celik (2007) proposed a generic model for fire and smoke detection without the use of sensors. Fuzzy based approach is used in this system. Color models such as YCbCr, HSV are used for fire and smoke detection. The fire is detected using YCbCr color model samples because it distinguishes luminance and chrominance. Y, Cb, Cr color channels are separated from RGB input image. A pixel is more likely a fire pixel if intensity of Y channel is greater than channel Cb and Cr.[14]

Cheng (2011) proposed a fire detection system based on Neural Network; here neural network is used in detection information for temperature, CO concentration, and smoke density to determine probability of three representative fire conditions. RBF neuron structure is used, the information regarding temperature, CO concentration, and smoke density are collected and data fusion is used to generate fire signal decision. The detectors have continuous analog outputs, when detection limit is exceeded the hardware circuit sends a local fire indication to fusion center, this force the system detectors to generate final decision. Single-sensor detector is used to generate the final decision.[15]

3. OVERVIEW

Overall, Forest fires are a global problem that has attracted considerable attention from researchers in recent years. Several studies have explored the use of drones for forest fire detection, including both manned and unmanned aerial vehicles. These studies have shown that dronesprovide a cost-effective and efficient means of monitoring large forest areas in real time. Moreover, drones equipped with high-resolution cameras can capture images and videos ofthe forest environment, which can be processed using computer vision techniques to detect potential fires. The field of computer vision has also witnessed significant advances in recent years, with various techniques being developed for image and video processing, object detection, and machine learning. These techniques have been applied to a wide range of applications, including forest fire detection. In particular, the HAAR Cascade Classifier algorithm has been widely used for object detection due to its high accuracy and computational efficiency.

4. PROPOSED SYSTEM

The system is designed with image processing techniques and using the camera and drone to obtain cost-effectiveness and probability, importance of the proposed system is to make a reliable, safe, and smart system. The platform uses a drone that has onboard computers and processing capabilities. The algorithm such as HAAR Cascade classifier of artificial intelligence and machine learning are used to get the results. The HAAR Cascade Classifier detects the presence of fire in some frames, if the number of frames in which the presence of fire was detected exceeds a certain number then the alarm-raises and an SMS is sent to the authorized user.

5. METHODOLOGY

Single-board computers that access the footage that the drone camera records frame by frame using OpenCV. and the fire is recognized if the number of frames is more than a certain value**.**

HAAR Cascade Classifier-based object detectionsystem
Utilizing a knowledge base, the HAAR cascade classifier is utilized to detect objects. The HAAR cascade classifier employs a dataset that was created during training with a set of fire-related images to detect the presence of fire in captured frames from adrone camera.

6. SYSTEM DESIGN

The flowchart of the proposed system is shown in Figure 1.

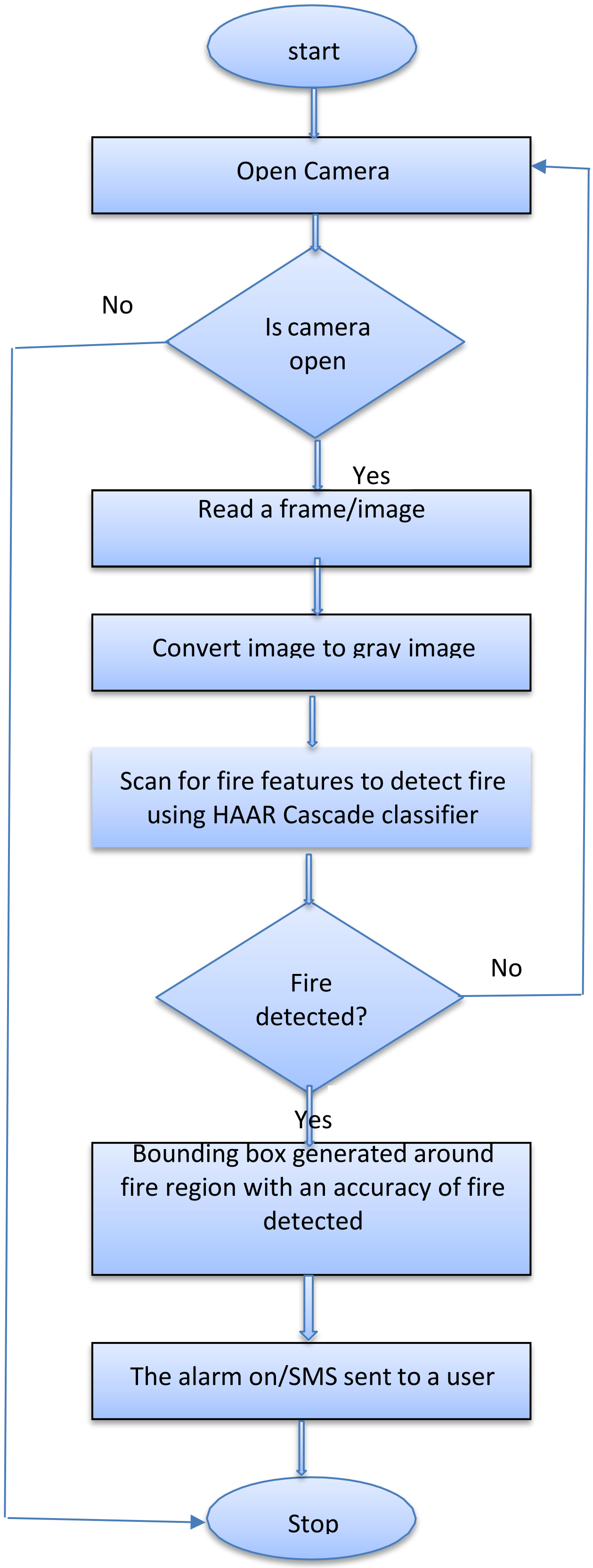

Figure 1. Flow-Chart of proposed system

First, the camera is set up, image from the camera would be processed with the HAARcascade and scanned for the fire features to detect fire, if a fire is present in the image, it will draw a bounding box around a fire and it will give the output as fire detected, also alarm is raised andSMS is sent to authorizedperson.

7. SYSTEM TESTING

The system is tested by considering the different distances and the different conditions of the fire. The below Table 1 and Table 2 gives a clear picture of the system testing results.

Results of tests at a distance of 100cm are shown in Table 1. For the very first test, we decided to keep the distance short. We varied the intensity of fire by using various sources of fire at different angles and the accuracy of the system was as follows:

Table1: Results at a distance of 100cm

Distance	Test no.	Real fire	Other light sources	Accuracy
100cm	1	Detected	Not Detected	90%
100cm	2	Detected	Not Detected	80%
100cm	3	Detected	Not Detected	80%
100cm	4	Detected	Not Detected	80%
100cm	5	Not Detected	Detected	40%

Average accuracy for the distance 500cm is 61%.

HAAR Cascade method out-performed compared to CNN with average accuracy of 74% when the distance is 100cm and 61% when the distance is 500cm, as shown in figure 4.

8. RESULTS AND DISCUSSION

The Figure 2 gives the output of the proposed system, when the captured video is imported the fire detection procedure starts and if the fire is detected then a bounding box around the fire is drawn with the percentage of accuracy. The accuracy of the fire is displayed on the screen as shown in figure 3 and figure 4 shows the average accuracy against distance. Then the alarm is raised and the SMS is sent using GSM, to the user or an Authorized person only if the fire is detected with the notification as 'FIRE DETECTED' as shown in figure 5. Figure 5 shows that the SMS was sent to the authorized person using GSM.

Figure 2: Fire Detection with a bonding box

Average accuracy for the distance 100cm is 74%.

Results of tests at a distance of 500cm are shown in Table 2. Then we changed the distance to more than 1 meter for detecting fires at long distances, the distances and angles of the fire were different this time. The accuracy of the system was as follows:

Table2: Results at a distance of 500cm

Distance	Test no.	Real fire	Other light sources	Accuracy
500cm	1	Detected	Not Detected	70%
500cm	2	Not Detected	Detected	60%
500cm	3	Not Detected	Detected	30%
500cm	4	Detected	Not Detected	65%
500cm	5	Detected	Not Detected	80%

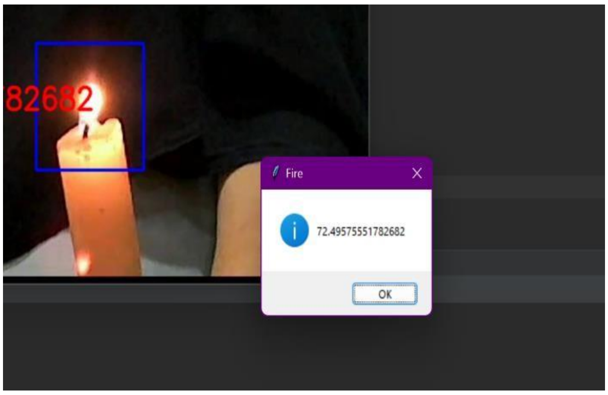

Figure 3: Fire Detection with accuracy

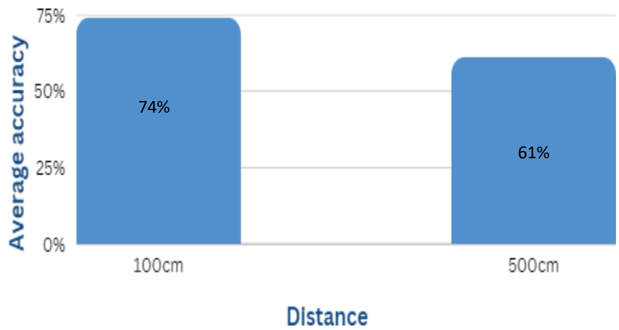

Figure 4: Graph of accuracy against distance

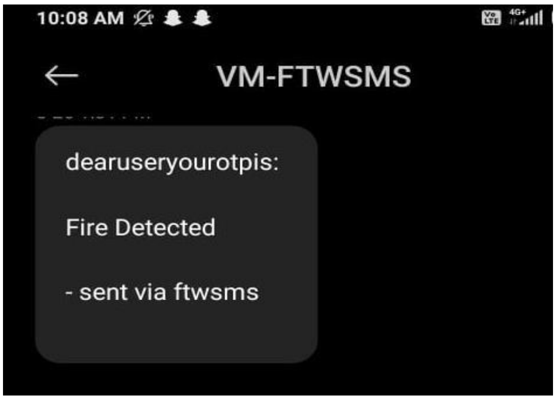

Figure 5: Notification sent via SMS

9. CONCLUSION

A drone-based fire detection system was developed using the HAAR cascade classifier and OpenCV. The system successfully demonstrated its ability to detect fire video captured from drone footage, providing early detection and enabling prompt responseto fire incidents. The integration of the HAAR cascade classifier, OpenCV, and image processing techniques enhanced the system's accuracy and robustness. The results showed that the system achieved high detection and average accuracy of 74% for 100cm distance and 61% for 500cm, rapid response time, and reliability.

10. REFERENCES

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