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Development of Fire Detection Algorithm at Its Early Stage Using Fire Colour and Shape Information

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Abstract. Fire can be defined as a state in which substances combined chemically with oxygen from the air and give out heat, smoke and flame. Most of the conventional fire detection techniques such as smoke, fire and heat detectors respectively have a problem of travelling delay and also give a high false alarm. The algorithm begins by loading the selected video clip from the database developed to identify the present or absence of fire in a frame. In this approach, background subtraction was employed. If the result of subtraction is less than the set threshold, the difference is ignored and the next frame is taken. However, if the difference is equal to or greater than the set threshold then it subjected to colour and shape test. This is done by using combined RGB colour model and shape signature. The proposed technique was very effective in detecting fire compared to those technique using only motion or colour clues.

1. Introduction

Fire can be defined as a state in which substances or materials combine chemically with oxygen from the air to give out heat, smoke and flame [1]. In general fire occurs only when 3 essential elements come together: heat (sufficient), material (Fuel), and oxygen as illustrated in Figure1. Fire plays very important role in human life. Human beings rely on fire for their cooking, warmth, blacksmith and industry applications. In spite of its numerous advantages fire can be dangerous if left uncontrolled. Such fire has the potential to cause physical damage like human burning, property/environmental destruction and water contamination. Fire can be characterized by the heat it generates, smoke, motion and irregular shape. This paper we restricted to class A and B fire formed by wood, papers, charcoal, rubber, petrol and kerosene etc. which are the most common fire occurring in our environment.

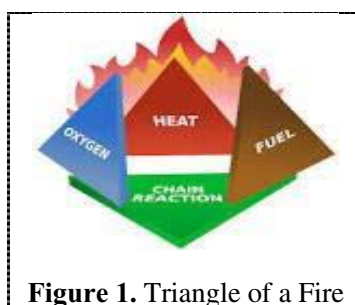


Figure 1. Triangle of a Fire



Fire can be characterized by the heat it generates, smoke, motion and irregular shape. This paper we restricted to class A and B fire formed by wood, papers, charcoal, rubber, petrol and kerosene etc. which are the most common fire occurring in our environment. In recent times many fire outbreaks were reported in Nigeria. For example [2] reported that about 80 fire disruption was cataloged in only 2015 in Kano state alone. Properties estimated to be valued more than to N185m were ruin by the fire disruption within the period and about 103 rescue teams were contacted with 10 false alarms available from members of the public. A total of 134 lives were saved from various incidents while 21 lives were lost. Reference [3] reported another Fire outbreak in Kano Sabon Gari Market where shops and properties worth millions of naira were destroyed and it spent more than 10 hours before it was finally put out. Conventional fire detection systems such as smoke and fire detectors are based on electronic sensors which are usually depend on heat and pressure. In the worst case scenario, if the sensors are damaged or not configured properly, these sensors can results false alarm. Also, the response time of proposed algorithm is faster compared to sensor-based fire detection system. However, the proposed technique does not require any type of condition to trigger and it has the ability to monitor a large area in both indoor and outdoor.

2. Related Work

This paper discusses the review work of fire detection using color models, motion or shapes to detect a fire. For example: A real-time video fire and smoke detection algorithm proposed by [4] which was based on foreground image accumulation and optical flow technique. Also, [5] proposed a system to detect a fire using color and shape through covariance matrix and send alarm using a mobile phone application. The mobile phone served as the receiving end and the user will be able to view and alert fire station. Reference [6] uses different color models to detect both fire and smoke. The color models are extracted using a statistical analysis of samples extracted from different type of video sequences and images. Reference [7] proposed a detection technique that uses YCbCr color space. In the event of fire outbreaks a frame is keep under consideration. If the area of the flame increases in a subsequent frame then an alarm is sounded. Reference [8] comes up with a technique using edge detection, color and motion to detect both fire and smoke. Reference [9] developed a method that extracts color and motion from video sequences to detect fire. The result of this paper is to identify color pixels in the scene and then identify fire region [10] focuses on optimizing the flame detection by identifying gray cycle pixels in the nearby flame, which is generated due to smoke in the area spread by flame.

3. Proposed Algorithm

The proposed technique uses background subtraction to detect changes in frames there by subjecting the result to colour and shape signature to detect a fire in both indoor and outdoor. Fig.3.1 shows the flow chart of the system.

3.1. Camera Details

In this work, a digital hand camcorder camera with resolution of 1280x720 pixels and 30 FPS frame rate with 5.1 megapixel CMOS image sensor having 2.0-inch LCD display was used for recording of the fire videos.

3.2. Detection of Fire Frames

Identifying moving objects from a video frame find to be very difficult in image processing technique. A common method used is to perform background subtraction that is to compare the current frame with reference frame. Usually, the first frame of the video which contain no object of interest is considered as the reference frame say frame (K).

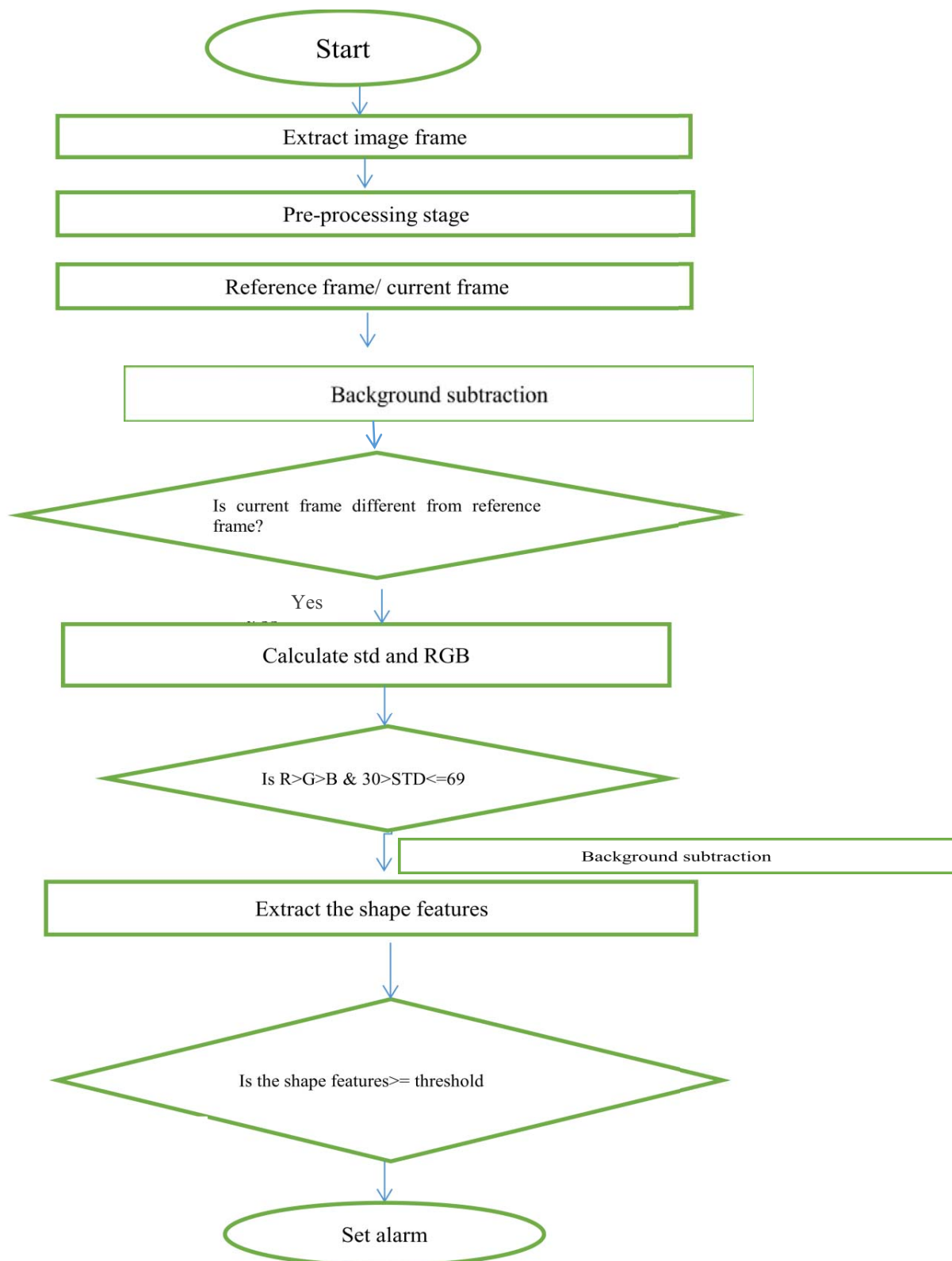


Figure 2: General Frame Work of the System

As the video advances, an object of interest starts appearing in the subsequent frames ($K+1$, $K+2$, $K+3$, ..., $K+N$). In order to detect the object of interest, the current frame say frame ($K+3$), is subtracted from the reference frame that is $((K+3) - (K))$, all the common pixels between the two frames will cancel out, the only pixel that will remain will be that belonging to the moving object in the current frame as illustrated in Figure 3.

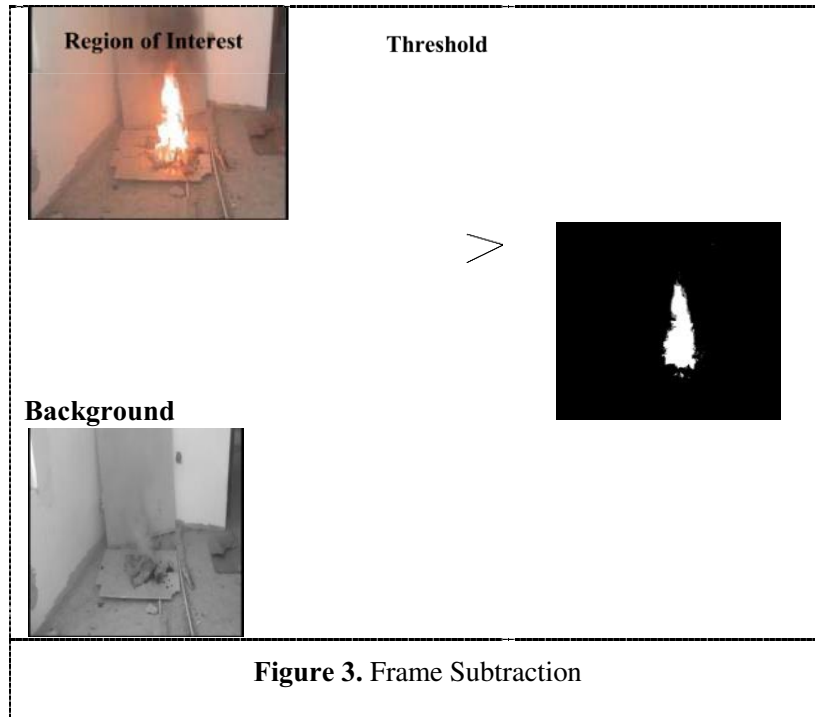


Figure 3. Frame Subtraction

The idea of background different method is to set the differences in pixel values between the current frame and background frame. If the result is less than the set threshold, the difference is ignored and the next frame is taken. However, if the difference is equal or greater than the set threshold, the different region is taken for segmentation.

4. Segmentation

Segmentation is a technique for discriminating the foreground image against the background (other regions in the image). In this paper, the threshold based segmentation method is used due to its simplicity and accuracy. The thresholding operation is a grey value remapping operation g defined by:

$$G(v) = \begin{cases} 0 & \text{if } v < t \\ 1 & \text{if } v \geq t \end{cases} \quad (1)$$

Where v represents a grey value and t is the threshold value. Thresholding maps a grey-valued image to a binary image. In the threshold approach once an appropriate threshold value t is selected (which was experimentally determined in this work as 80 (i.e. $t = 80$)) the back ground pixels are forced to black while the foreground ones are converted into high intensity as shown in Figure 4.

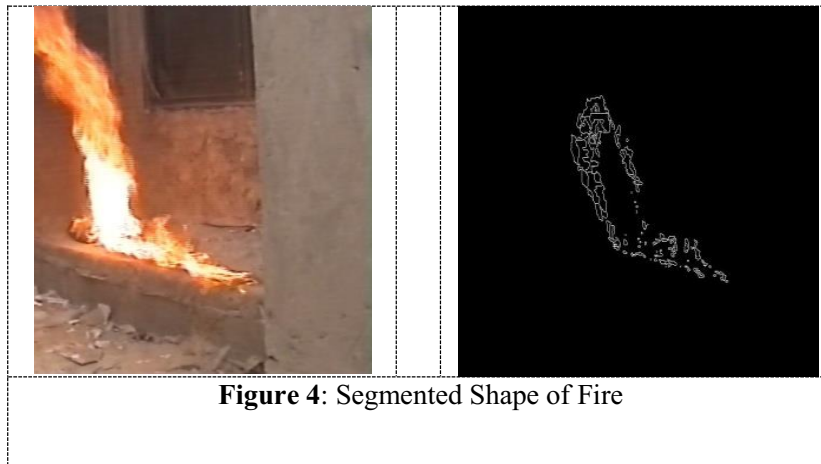


Figure 4: Segmented Shape of Fire

4.1. Fire Detection Using Colour

Color is very important attribute for object recognition. Fire can be described using its color properties which are resolved into three basic elements i.e. Red, Green and Blue (RGB). [10] decomposed RGB color model to detect color information. He further established the ratio of these color and concludes that a fire has R-component greater than G- component and G-component greater than blue. $R > G$ & $G > B$. Thus, fire color has R being the dominant color channel in an RGB image of fire. The correlation between the 3 channels is shown in Figure 5.

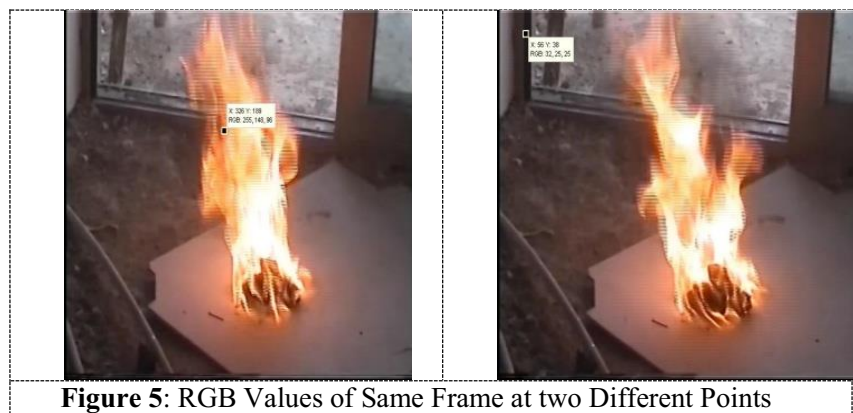


Figure 5: RGB Values of Same Frame at two Different Points

Figure 5a and b are the RGB values of same frame at two different points. Fig. 5 (a) shows the coordinate ($x=326, y=189$) with the corresponding values (255,148,96). This justifies the second RGB condition that $R > G > B$ which qualify the region as a fire while fig.5(b) coordinates ($x=56, y=38$) with the corresponding values (32,25,25) doesn't satisfy the RGB condition and therefore, it disqualifies the region as non-fire.

5. Fire Detection Test

Shape is a feature of object geometry that is variant with respect to time translation, rotation and scaling. Several algorithms were presented in the past by many researchers such as Box-counting method, Perimeter method, signature, skeleton, edge detection and contour extraction, etc. [11]. In this paper we employed a shape signature method to extract the shape of a fire. A shape signature is 1-D functional representation of a boundary and may be generated by plotting the distance from centroid to the boundary

as a function of angle. The basic idea is to reduce the boundary representation to 1-D function which presumably easier to describe the original 2-D boundary [12]. Based on the assumption of uniformity in scaling with respect to both axes, sampling is taken at equal interval of theta, changes in size of a shape result in the amplitude values of the corresponding signature. The signature of the given boundary is given as

$$[st, angle, x_0, y_0] = signature(b, x_0, y_0) \quad (2)$$

Where b is n_p by 2 array containing xy coordinates of the boundary ordered in clockwise or counterclockwise direction. The amplitude of the signature as a function of increasing angle and is output in st . The figures below show the signature of different shapes of objects. The basic idea of signature is to remove dependency on size while preserving the fundamental shape of the waveforms. This clearly differentiates the fire and non- fire frames by the uniqueness of the signature of an individual frames and yields better result.

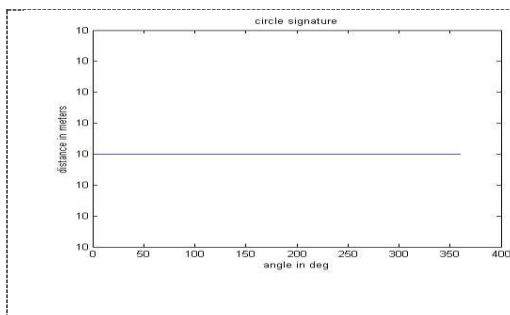


Figure 6. A Signature of a Circle

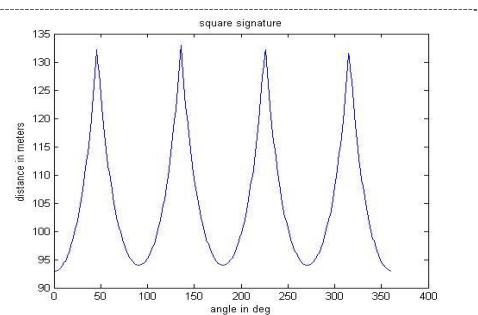


Figure 7. A Signature of a Square

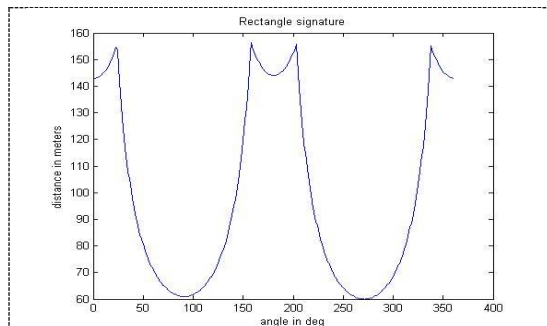


Figure 8. A Signature of a Circle

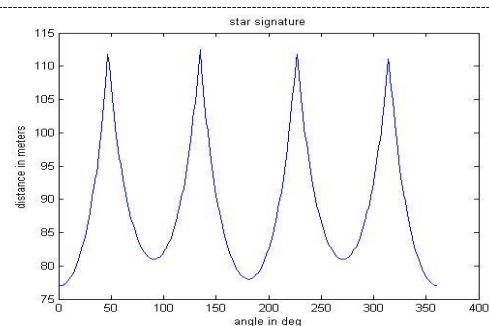


Figure 9. A Signature of a Square

6. Experimental Result

6.1. Fire Detection using Colour

Colour is very important tool in fire detection. Many algorithms were developed to detect a fire as discussed above. In this work, 10 video clips were sample from the database to test the algorithm using colour. Table 1 show the summary of the results obtained from colour.

Table 1 Summary Result of Colour Fire Detection

Video Clip	Total Number Of Frames	Rejected Frames	True Positive (TP)	False Positive (FP)	True Negative (TN)	False Negative (FN)
Video D1	275	68	124	48	19	16
Video D2	550	97	331	86	24	11
Video D3	425	52	318	25	11	19
Video D4	625	49	322	187	51	33
Video D5	500	68	376	18	21	17
Video D6	425	24	320	36	23	22
Video D8	500	69	359	51	13	8
Video D10	650	35	155	301	118	41
Video D11	550	216	118	161	25	30
Video D14	250	21	165	31	19	14
TOTAL	4750	699	2588	944	324	211

[13] Describe the Sensitivity, Specificity and Accuracy in terms of true positive (TP), true negative (TN), false negative (FN), and false positive (FP). Given that [13],

$$\text{Sensitivity} = \frac{TP}{(TP + FN)} = (\text{Number of true positive assessment}) / (\text{Number of all positive assessment}) \quad (3)$$

$$\text{Specificity} = \frac{TN}{(TN + FP)} = (\text{Number of true negative assessment}) / (\text{Number of all negative assessment}) \quad (4)$$

$$\text{Accuracy} = \frac{(TN + TP)}{(TN + TP + FN + FP)} = (\text{Number of correct assessments}) / (\text{Number of all assessments}) \quad (5)$$

From Table 1,

$$\text{SENSITIVITY (True Positive Rate (TPR))} = TP / (TP + FN) \\ TPR = 2588 / (2799) = 0.9246 = 92.461\%$$

$$\text{SPECIFICITY (True Negative Rate (TNR))} = TN / (FP + TN) \\ SPC = 324 / (1268) = 0.2555 = 25.552\%$$

$$\text{FALSE DETECTION RATE (FDR)} = FP / (FP + TP)$$

$$FDR = 944 / (3532) = 0.2673 = 26.73 \%$$

The accuracy of the algorithm specifies the ability of the algorithm in detecting the region of interest (ROI).

$$\text{Accuracy} = (TP + TN) / (TN + TP + FN + FP) \text{ } 100\% \quad (6)$$

$$\text{Accuracy} = 2588 / (4067) * 100\% = 63.634\%$$

6.2. Fire Detection Shape (Signature)

The concept of signature is to extract dependency on size while retaining the fundamental shape of the waveforms. Signature method helps in enhancing the technique by reducing the false detection in using colour. Table 2 shows the summary detection using a shape (Signature). From Table 2. [13] stated that :

$$\text{SENSITIVITY (TPR)} = TP / (TP + FN) = 2793 / 2936 = 0.9513 = 95.13\%$$

$$\text{SPECIFICITY (TNR)} = TN / (FP + TN) = 245 / 690 = 0.3551 = 35.51\%$$

$$\text{False Detection Rate (FDR)} = FP / (FP + TP) = 445 / 3238 = 0.1374 = 13.74\%$$

$$\text{Accuracy} = ((TN + TP) / (TN + TP + FN + FP)) * 100\% = 3038 / 3626 = 0.83784 = 83.784\%$$

The accuracy of the algorithm using shape was found to be 83.784%.

Table 2 Summary Result of Fire Detection using Shape

Video clip	Total number of frames	Rejected frames	True positive (TP)	False positive (FP)	True negative (TN)	False negative (FN)
Video D1	275	68	163	6	16	7
Video D2	550	93	390	27	21	19
Video D3	425	41	356	5	12	11
Video D4	625	17	322	187	9	13
Video D5	500	68	378	16	23	15
Video D6	425	14	340	31	18	22
Video seven D8	500	65	412	11	5	7
Video eight D10	650	351	147	24	118	10
Video nine D11	550	226	98	131	19	30
Video ten D14	250	21	187	7	4	9
TOTAL	4750	964	2795	445	245	143

The proposed technique using both color and shape result in better detection despite the present of lightening and fire color objects by achieving 83.784% accuracy.

7. Conclusion

In this work, fire detection system was proposed, which is based on video image processing techniques. A number of sequential frames from original video clips were used which consists of fire and non-fire frames. The proposed algorithms differentiate the fire pixel frame from non-fire pixel frame using RGB colour model, and shape. The system has a better performance accuracy of 83.784% compare to [16] with 80.64%.

Thus application of the proposed fire detection system will ensure a better system performance in term of reducing the false alarm and better early fire detection. The performance of this technique can further be improved by detecting the growth of fire, along with the previous fire detection technique.

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