FIRE DETECTION ALGORITHM USING IMAGE PROCESSING TECHNIQUES

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ABSTRACT

Lately fire outbreak is common issue happening in Malays and the damage caused by these type of incidents is tremendous toward nature and human interest. Due to this the need for application for fire detection has increases in recent years. In this paper we proposed a fire detection algorithm based on image processing techniques which is compatible in surveillance devices like CCTV, wireless camera to UAVs. The algorithm uses RGB colour model to detect the colour of the fire which is mainly comprehended by the intensity of the component R which is red colour. The growth of fire is detected using sobel edge detection. Finally a colour based segmentation technique was applied based on the results from the first technique and second technique to identify the region of interest (ROI) of the fire. After analysing 50 different fire scenarios images, the final accuracy obtained from testing the algorithm was 93.61% and the efficiency was 80.64%.

***Keywords**: Fire Detection, Image Processing, Signal Processing.*

1. Introduction

Application of fire detection as tool has increase to due to the frequent occurrence of extended fire with consequences on human health and security. This current detection methods which are based on electronic sensors are usually depend on heat and pressure sensors. However those methods has a fatal flaw where they will only work when a certain condition has been reach. In the worst case scenario is the sensors are damaged or not being configure properly can cause heavy casualty in-case of real fire. To solve these problems in electronics surveillance cameras being installed. Due to this there is an increase of need for fire detection based on computer vision for such devices. Such devices include a wide range of CCTV, wireless camera even to UAVS.

These type of systems offer several distinguish advantages over those traditional detection methods. For example the cost of using this type of detection is cheaper and the implementation of this type system is greatly simpler compare to those traditional methods. Secondly the response time of fire detection system is faster compare to any other traditional detection methods since a vision sensor-based fire detection system does not required any type conditions to trigger the sensors and it has the ability to monitor a large area depends on the camera used. The most benefit of these type of system is the fire source can be saved in a form of image or video which can used for promoting the diversification of the fire detection method greatly.

In this paper, we proposed an algorithm which combines colour information of the fire with the edge of the fire information. Then with the combined results from both this techniques, a parameter is created to segment out the necessary details from the images to detect and identify the fire.

2. Related Work

There are several research have been done in this area. This include Ti Nguyen et al., (2013) developed a method that extract colour and motion from video sequences to detect fire. The results of this paper was able to produce a method which has the ability to perform the region growing segmentation to identify colour pixels in the scene and then identify fire region. The methodology used are YCBCR colour space model and region growing technique which compares all unallocated neighbouring pixels to the region. Punam et al., (2012) suggested a method with uses RGB colour model and background subtraction method. This method does have two major advantages which are modes computational load and fast processing but greatly effects the quality of the fire detected. Jareerat al., (2012) presented a method which uses HSV and YCbCr colour model with conditions to separate brightness of the fire from the background and ambient light. Meanwhile research by Wenhao and Hong (2012) extracted flame objects by iterative adaptive threshold techniques. While Tian Qiu et al., (2012), proposed an algorithm which worked on edge detection for a similar purpose which is to detect fire. In this algorithm the fire was detected by identifying the area between thermo chemical and the non-thermo reaction. Result of this experiment shows that edge of the fire was able to be detected clearly and non-stop. In contra to Petro et al., (2012), where they presented a real-time algorithm which works on the background subtraction method. An algorithm which was based detection and tracking was used with the objectives to reduce false alarm rate of fire which frequently happen with the traditional electronic methods. Lei and Liu (2013), used frame differences, median filters and Bayes classifier to detect flame. In Celik (2010), the algorithm is divided in two parts, which are colour modelling and background registration.

3. Proposed Algorithm

Our proposed method as below in figure 1.0. The first step in our method is to detect the colour of the fire which is mostly red in colour. Then we used the sobel edge detection on the original image to detect the edge of the fire while removing threshold which is less than 100. Then we applied the segmentation technique which used the combine the result from the first technique and second technique to separate the ROI of the fire from the background.
The figure below show the flow of the proposed algorithm.

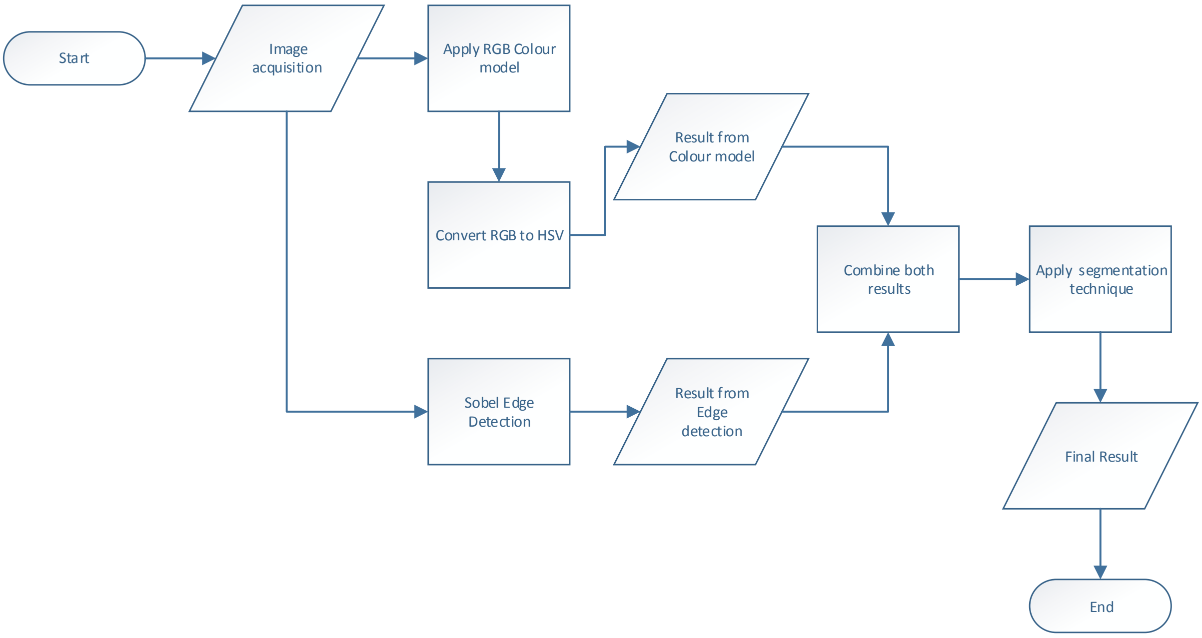

Figure 1.0: Show the flowchart of the algorithm

3.1 RGB Colour Model

A fire image can be described by using its color properties. There are three different element of color pixel: R, G and B. The color pixel can be extracted into these three individual elements R, G and B, which is used for color detection.
RGB color model is used to detect red color information in image. In terms of RGB values, the corresponding inter-relation between R, G and B color channels: R>G and G>B. The combined condition for the captured image can be written as: R>G>B. In fire color detection R should be more stressed then the other component, and hence R becomes the domination color channel in an RGB image for fire.

This imposes the condition for R as to be over some pre-determined threshold value RTH.
All of these conditions for fire color in image are summarized as following:

Condition1: R > RTH
Condition2: R > G > B.

Then the result then is need to convert to HSI color model where H represent hue, S represent saturation and I represents internsity. The converstion can be done using the following formula;

$$H = \begin{cases} \boldsymbol{\theta} \ if \ B \leq G \\ 360 - \boldsymbol{\theta} \ if \ B > G \end{cases}$$

With

$$\boldsymbol{\theta} = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)]}{[(R-G)^2+(R-G)(G-B)]^{1/2}}\right\} \qquad (1)$$

$$S = 1 - \frac{3}{(R+G+BA)}\ [\min(R,G,B)] \qquad (2)$$

$\mathrm{I} = \frac{1}{3}(R + G + B)$ (3)

Where R,G and B represent the component of Red,Green and Blue within the image. The result of this technique as below in figure 2.0.

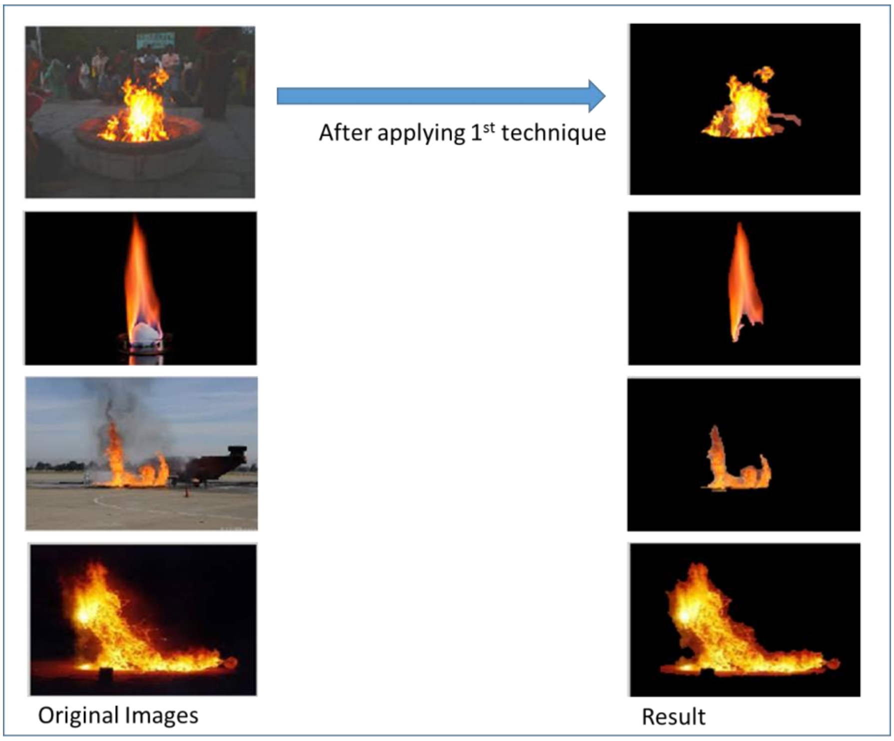

Figure 2.0: Show the results from the 1st technique.

3.2 Sobel Edge Detection

The next step will be to use the sobel edge detector to detect the growth of fire within the images. This can be done by applying 3x3 mask to the images. Convolution is both commutative and associative and is given as below;

$\nabla f \cong |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| + (z_3 + 2z_6 + z_9)\text{-}(z_1 + 2z_4 + z_7)|$

The mask which was used in this techniqes are as below;

$M_x = \begin{matrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{matrix}$ and $M_y = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix}$

The result of this technique as below in figure 3.0.

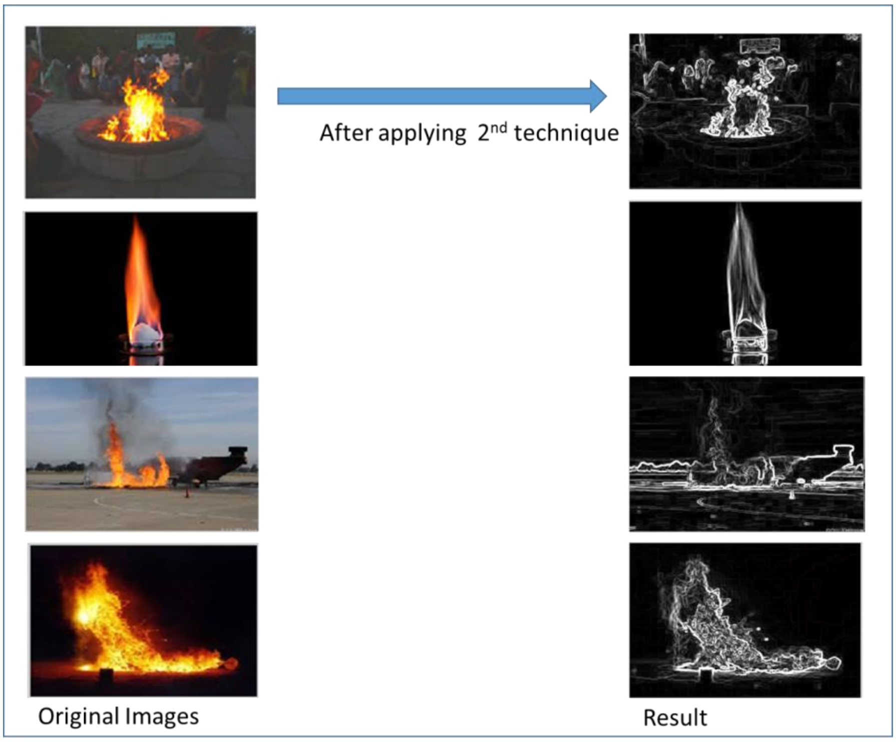

Figure 3.0: Show the results from the 2nd technique.

3.3 Segmentation Technique

The final technique used in this algorithm is segmentation technique which was used to segmented fire from the non-fire background. The first step done by this technique is to specific the colour range for segmented process in the ROI. However in this algorithm that we proposed, this has been done in the first technique. Based on that parameter the following formula is used;

$$D(x,m) = \left\|x - m\right\| \qquad (4)$$

$$= \{(x,m)^T(x-m)\}^{1/2} \qquad (5)$$

$$=[(x_R-m_R)2+(x_G-m_G)2+(x_B-m_B)^2)^{1/2} \qquad (6)$$

The distance is compare with the threshold value. If D(x,m) ≤ threshold value, the point belong to ROI of the fire. Otherwise they are not part of the ROI of can be consider as background. The region which separates the ROI and non-ROI is detected using the 2nd technique which is the sobel edge detection. The finaly results of all this techniques are as below in figure 4.0.

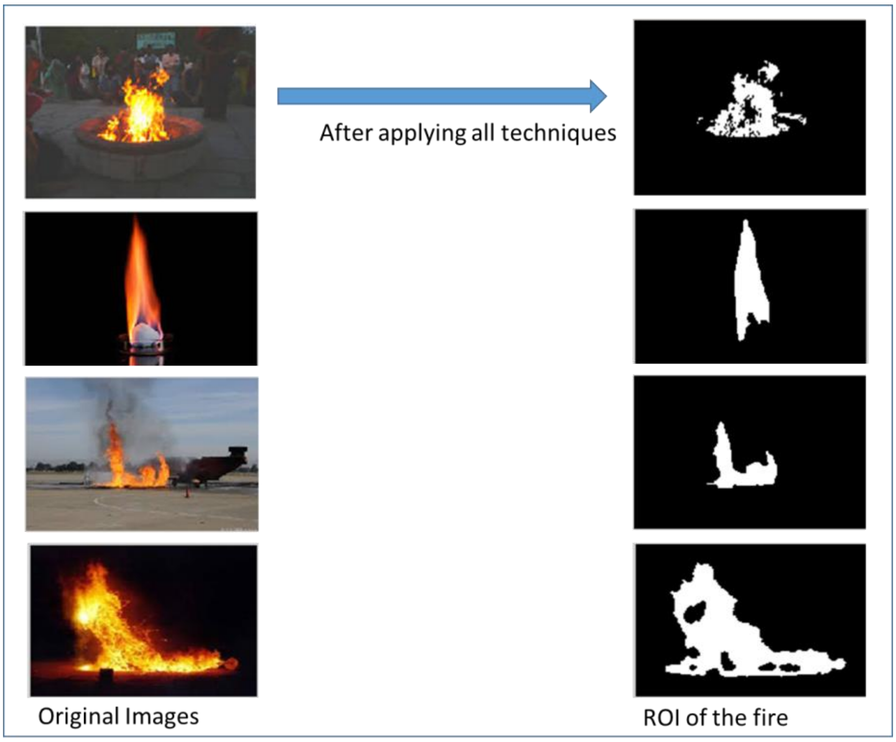

Figure 4.0: Show the final results from the algorithm that we proposed.

4. Result and Analysis

Finally validation was carried out to evaluate the algorithm based on the 50 images. This validation process uses a truth model, with which the results was compared. The contingency table for the sensitivity and specificity analyses of the validation algorithm is given in Table 1.0. The true positive (TP) and true negatives (TN) are correct classification. A false positive (FP) is when the outcome of the algorithm is incorrectly predicted, when the in reality it is actually present in the image.

The accuracy of the algorithm specify the ability of the algorithm in detecting the ROI.
Accuracy = TP/ (TP+TN)*100%

The efficiency test is given as
Efficiency = (TN+TP/TN+TP+FN+FP)*100%

Table 1.0: 50 different fire scenarios images.

Data set	Human expert	Detected by the algorithm	Missed by the algorithm
1	ROI present	True Positive(TP)	False Negative(FP)
2	ROI present	True Positive(TP)	False Negative(FP)
3	ROI present	True Positive(TP)	False Negative(FP)
4	ROI present	True Positive(TP)	False Negative(FP)
5	ROI present	True Positive(TP)	False Negative(FP)
6	ROI present	True Positive(TP)	False Negative(FP)
7	ROI present	True Positive(TP)	False Negative(FP)
8	ROI present	False Positive(FP)	True Negative(TN)
9	ROI present	False Positive(FP)	True Negative(TN)
10	ROI present	False Positive(FP)	True Negative(TN)
11	ROI present	True Positive(TP)	False Negative(FP)
12	ROI present	True Positive(TP)	False Negative(FP)
13	ROI present	True Positive(TP)	False Negative(FP)
14	ROI present	True Positive(TP)	False Negative(FP)
15	ROI present	True Positive(TP)	False Negative(FP)
16	ROI present	True Positive(TP)	False Negative(FP)
17	ROI present	True Positive(TP)	False Negative(FP)
18	ROI present	True Positive(TP)	False Negative(FP)
19	ROI present	True Positive(TP)	False Negative(FP)
20	ROI present	True Positive(TP)	False Negative(FP)
21	ROI present	True Positive(TP)	False Negative(FP)
22	ROI present	True Positive(TP)	False Negative(FP)
23	ROI present	True Positive(TP)	False Negative(FP)
24	ROI present	True Positive(TP)	False Negative(FP)
25	ROI present	True Positive(TP)	False Negative(FP)
26	ROI present	True Positive(TP)	False Negative(FP)
27	ROI present	True Positive(TP)	False Negative(FP)
28	ROI present	True Positive(TP)	False Negative(FP)
29	ROI present	True Positive(TP)	False Negative(FP)
30	ROI present	True Positive(TP)	False Negative(FP)
31	ROI present	True Positive(TP)	False Negative(FP)
32	ROI present	True Positive(TP)	False Negative(FP)
33	ROI present	True Positive(TP)	False Negative(FP)
34	ROI present	True Positive(TP)	False Negative(FP)
35	ROI present	True Positive(TP)	False Negative(FP)
36	ROI present	True Positive(TP)	False Negative(FP)
37	ROI present	True Positive(TP)	False Negative(FP)
38	ROI present	False Positive(FP)	False Negative(FP)
39	ROI present	False Positive(FP)	True Negative(TN)
40	ROI present	False Positive(FP)	True Negative(TN)
41	ROI present	True Positive(TP)	False Negative(FP)
42	ROI present	True Positive(TP)	False Negative(FP)
43	ROI present	True Positive(TP)	False Negative(FP)
44	ROI present	True Positive(TP)	False Negative(FP)
45	ROI present	True Positive(TP)	False Negative(FP)
46	ROI present	True Positive(TP)	False Negative(FP)
47	ROI present	True Positive(TP)	False Negative(FP)
48	ROI present	True Positive(TP)	False Negative(FP)
49	ROI present	True Positive(TP)	False Negative(FP)
50	ROI present	True Positive(TP)	False Negative(FP)

Hence based on our analysis over the 50 images.
Accuracy = 93.61%
Efficiency = 80.64%

5. Conclusion

We proposed a fire detection algorithm based on image processing techniques. The algorithm uses RGB colour model to detect the colour of the fire which is mainly comprehended by the intensity of the component R which is red colour. The growth of fire is detected using sobel edge detection. Finally a colour based segmentation technique was applied based on the results from the first technique and second technique to identify the region of interest (ROI) of the fire. The algorithm works very well when there is a fire outbreak. The overall accuracy of the algorithm is greater than 90%, indicating the effectiveness and usefulness of the algorithm. In future work, a real-time based algorithm could be consider as it might increase the efficiency of the algorithm which is currently 80.64%.

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