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Research Article:

Image Processing Techniques-based fire detection

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Abstract

In this paper different fire detection systems and techniques has been reviewed, many techniques have been developed for the purpose of early fire detection in different scenarios. The most accurate technique used among all these methods is Image Processing based Techniques. Different color models like RGB, HSI, CIE L*a*b and YCbCr have been used along with different edge detection algorithms like Sobel and Novel edge detection, finally the color segmentation technique was discussed in the review paper. All the mentioned methods in these papers have significantly proved to detect fire and flame edges in digital images with a timely manner, which has a huge impact on saving life and reducing loss of life.

1. Introduction

A Forest is considered as a vital part of earth as it’s considered the largest storehouse of carbon after the oceans, it also plays an important role in climate moderation, creating a habitat for animals and livelihoods for humans and prevents soil erosion (Hanamaraddi,2016) Unfortunately, due to the forest fires, hundreds of millions of hectares are destroyed, causing a severe damage and devastation to the ecological system and infrastructure (Hanamaraddi,2016). Most of the issues occur due to disability of detecting the fire in the early stages of its ignition as forests are usually remote and far from civilization (Alkhatib 2014; Giwa and Benkrid 2018). The first use of fire detection tools dates back to 1849-1940, using thermal detectors. The first fire detection system was used in the US, after the invention of telegraph in 1852 (Bistrović, 2013). In Europe, bells were used in pre-assigned combination to give signals (Bistrović, 2013). Between 1920-1960, many smoke detectors were used for the first time that proved to decrease of death rate by %41. Smoke detectors passed through four generations since 1920 to the current date, with each generation, new developments and improvements were done on the detectors (Bistrović, 2013). Flame detector is an another important aspect in fire detection that was used along with smoke detectors. Fiber optic cables can also be used as a fire detector which depends on the use of laser beam, high temperature causes expansion of the tubes filled with wax which will cause the deformation, and this leads to the change in the parameters of the laser beam, But the use of this system is too expensive, thus it's not the most common method of fire detection (Bistrović, 2013). Nowadays, several different modern methods are in use for fire detection. These methods are ranged from human observation to monitoring towers along with the use of satellite, areal monitoring systems, CCTV (closed-circuit television) and wireless cameras (Alkhatib, 2014). Many fire detection algorithms were developed using image processing techniques that can be blended with surveillance devices like CCTV, wireless cameras and unmanned aerial vehicles. Surveillance systems which contain CCTV, wireless cameras and UAVs (Unmanned aerial vehicles) (Alkhatib, 2014), can be improved with the use of image processing techniques which based on a process of improving the quality of an image to sake an easy interpretation by a computer (Zarkasi et al., 2019). Image processing has applications in several different areas including Agriculture, Computer vison, biometric verification (Sridhar, 2019), face detection, digital video processing, remote sensing, medicine, signature recognition, underwater image enhancement and restoration and character recognition (Padmappriya and Sumalatha, 2018). Most image processing techniques are based on processing of two dimensional image (Chitradevi and Srimathi, 2014). In image processing, a fire can be defined by its color (Patel and Tiwari, 2012), (Poobalan and Liew, 2015), different color models can be used for this purpose. Color model is the way of defining color, and how the color shows up on a display using computer screen or on a paper. In this review paper, four types of color models are reviewed which are RGB (Red, Green, Blue) (Celik 2010; Patel and Tiwari 2012; Poobalan and Liew, 2015); (Hanamaraddi 2016); Zarkasi et al. 2019), YCbCr (Y stands for luma or brightness, Cb is blue minus luma (B-Y), and Cr is red minus luma (R-Y)) (Patel and Tiwari 2012; Hanamaraddi 2016), another color model is CIELAB (International Commission on Illumination) (Celik, 2010) and HSI color model (H: hue, S: saturation, I: intensity). As another method for detecting fire edge detection is considered as one of the most important technique in fire and flame detection, as it can be used as a foundation of further processing (Qiu et al., 2012; Poobalan and Liew 2015; Zarkasi et al. 2019). Edge detection has several benefits in this field of study, including the reduction of processing time and emphasizing the interesting objects in the image and filtering unwanted noises in the background of the image, it can also be used for the segmentation of group of flames which can be used for monitoring multiple flames [Ref]. Detecting flame edges in a timely manner is a key to fire alarm trigger and providing fire fighters with details regarding the type of fire (Toreyin and Cetin 2007; Qiu et al. 2012). Noise reduction is another important step in image pre-processing using different filtering methods such as, median filter that can be used to remove noise from an image while preserving the edges (Lei and Liu, 2013). Different set of algorithms can be used to get a promising result regarding the flame edge detection. Segmentation process can be used to identify a fire zone from a non-fire zone (Poobalan and Liew, 2015). This review paper is divided into four sections: Section 1 is an introduction of the forest fire detection systems. Section 2 contains methodology for color models, noise reduction, edge detection and color segmentation. Section 3 includes results and discussions; Section 4 is conclusion. The aim of this review paper is to discuss and compare different researches using different image processing techniques in the field of fire detection.

2. Literature Review

Fire edge detection is the process of identifying the boundary between thermochemical and non-thermochemical areas of the fire. The process is a forerunner of image-based flame monitoring, early fire detection, fire evaluation and flame and fire parameter's determination. Several methods of edge-detection have been used to determine the flame edges. An algorithm has been developed for continuous and clear flame and fire edge detection. The algorithm proved to be successful in identifying irregular flame edges and it has an advantage at which the detected flame and fire edge are clear and continuous, also in different conditions, the parameters of the algorithm can be adjusted automatically. Based on this method, expected that in-depth understanding and advanced combustion flame monitoring can be done through the flame edge-detection algorithm. The algorithm has proved necessity of using image processing and safety engineering analysis (Qiu et al. 2012). (Poobalan and Liew, 2015), have proposed an algorithm uses two techniques for fire detection; the first one was based on the RGB color model for fire detection and the second technique has proposed Sobel edge detection technique for determining the fire growth within the image, finally this study proposed a color based segmentation technique that followed by the merge of results that have been gained from implementing all the steps of both techniques. The study concludes that the algorithm proves to be working very well during a fire outbreak with an accuracy of more than 90% and efficiency of 80.64%. The process of forest fire monitoring can be done using satellites or UAVs (Unmanned aerial vehicles), and then the image is acquired and interpreted by a computer so that to make it understandable by humans. (Zarkasi et al., 2019) has proposed a study that used color filtering method for determining the region and the location of the fire in the image on a peatland using HSV and thresholding value. Based on the results, when using basic colors as the background (red, green, blue and yellow) within 40cm distance from the camera, the colors are not detected as a fire by using predefined value of HSV of fire pattern as shown in Figure 4 in reference (Zarkasi et al., 2019). Based on the calculation of the average HSV value of each object, a single HSV value for fire detection test (hue: 0-18, saturation: 74-166 and values: 200-230) can be used as color filtering for detecting fire parameters and also as a pattern threshold. Table 1 in reference (Zarkasi et al., 2019) shows that the best values of HSV are hue within the range of 0-16 up to 0-20, saturation within the range of 74-164 up to 74-168 and value in rage of 200-228 up to 200-233. By using Matlab, testing the results of color filtering HSV value can be seen in table 2 in reference Zarkasi et al. (2019). According to table 3 in the reference (Zarkasi et al., 2019), the error percentage is 8.88% caused by S values. To obtain good results of fire detection, the study depended on using a fire detector quadcopter flying above the fire object from different heights, the result shows that different height levels below 7m are considered to be more accurate in getting good results in detecting the fire as shown in table 3 in reference (Zarkasi et al., 2019). (Patel and Tiwari, 2012) have focused on fire detection techniques consisting of color detection, motion detection and area dispersion to detect a fire in a video. In this study YCbCr color model has been used due to the advantage of its ability in distinguishing luminance information from chrominance information. The study also focused on a motion detection at which current frames are compared to the previous frames in the video in order to detect moving pixels. The combination of motion, color and area are used for fire detection in the video data. The study concludes that texture or shape information can be used to improve the performance of fire detection system. An another study to detect a fire inside a building image processing in order to prevent deaths and property damage due to the fire outbreak (Seebamrungsat et al. 2014). In this study HSV and YCbCr models have been used to separate orange, yellow and high brightness light from the background and ambient light. Based on the differences between frames in the input video which can be real-time video from any web camera, the fire growth is analyzed and calculated. This system has shown accuracy of more than 90% to detect a fire in early stage that helps rescue life and reduces damages in properties. The reason of using this methodology is the effectiveness of YCbCr model to separate the luminance from chrominance compared to other color models as RGB. By considering fire image's statistical parameters in YCbCr color model, the method has proved to separate pixels of fire flame and high temperature fire center pixel successfully. RGB images were used as an input that followed by converting it to YCbCr image, and afterwards mean and standard deviation of that image was calculated. As a post process in this study, four rules were used to classify the fire pixels, two rules for segmenting fire flame region and another two rules for segmenting the fire center region of high temperature area. The method was applied on three images, first image that contains a fire, second image that contains similar scenes like a fire and the third image that contains the regions similar to fire center. The study has shown that the system can be used for forest fire detection with 99.4% detection rate and %12 of error rate (Hanamaraddi, 2016).

3. Theoretical concepts of fire detection

There are different color models that can be used to define colors that describe how the colors appear on a computer screen or on paper. It can also be defined as a representation of contained colors in a digital form (Ibraheem et al., 2012). Each of these color models can be used in different applications depending on the required task (Ford and Roberts, 1998). The conversion from one color space to other facilitate the detection process

3.1 RGB to HSI Conversion

RGB color model name has been derived from the primary colors (red, green and blue), with the description of color properties, a fire image can be color pixel can be extract into these elements R, G and B (Bistrović, 2013). RGB Color model can be used for fire detection through the detection of red color in an image. In the process of detecting a fire, R can be the dominant color channel in a fire image. This enforces a condition of R with pre-calculated recognized. In RGB color model, Color pixel have three different elements: R, G and B, for the sake of color detection, the threshold value RTH (Poobalan and Liew, 2015). These conditions of fire color are shown as followings:

Condition one: $R > RTH$

Condition two: $R > G > B$

RTH: value of red color threshold of fire (Patel and Tiwari 2012). RGB can be converted to HSI color model (H stands for hue, S stands for Saturation and I stand for intensity) to sake detecting fire in an image at which. The conversion from RGB to HIS can be done using the following equation:

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

With

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

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

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

R represents component of Red,
G represents component of Green and Blue represents the component of Blue within the image.

3.2 RGB to CIE L*a*b conversion

CIE color space is a mapping system that uses Tristimulus values (combination of three color values similar to red/green/blue). The CIE system characterizes colors by a luminance parameter Y and two color coordinates x and y. CIE has two color spaces which are CIEluv and CIELab (Ford and Roberts, 1998).
The CIE L*a*b is a color space defined by the international commission on illumination at which colors are defined in three values, L stands for perpendicular lightness, a* and b* stand for red, green, blue and yellow (Celik, 2010).

3.3 RGB to YCbCr conversion

YCbCr is a color space that can be represented in three components, Y a luminance component which also refers to the color brightness which is also the light intensity of color which is more sensitive to human eye, Cb and Cr are blue and red components related to chroma component (Ganesan et al., 2015). This color space can be used for fire detection due to its ability in distinguishing luminance from chrominance information compared to other color spaces.

3.4 Edge Detection

Edge detection is considered as one of the important steps in image processing and analysis. In a digital image of fire, the brightness of the flame region is higher than other region of that image. Flame edge detection can be defined as the process of detecting a border of the area where there is a thermochemical reaction and the area where there is no reaction (Poobalan and Liew, 2015). Detecting of flame edge has the advantages of reducing processing time to determine a fire area and differentiate it with a non-fire area, and alsofacilitate segmentation of flame groups. There are several methods for flame edge detection including Sobel edge detection, (Kalpana and Padmaa ,2014). and Novel edge detection (Qiu et al. 2011; Kalpana and Padmaa 2014).

3.5 Sobel Edge Detection

Sobel operator is an algorithm that is used to detect the fire growth in an image. It calculates the gradient intensity at each pixel within the image. The operator uses two sets of 3x3 kernels, one for the changes in the horizontal direction and one for the changes in the vertical direction (Poobalan and Liew, 2015).

3.6 Novel edge detection algorithm

This algorithm aims to detect flame edges in a better way compared to the other methods by aiming to detect a continuous edge. The algorithm is explained in the following steps (Qiu et al. 2011; Kalpana and Padmaa 2014):

1. Grey level adjusting of the flame image based on its statistical distribution.
2. Noise elimination through image smoothing.
3. Using Sobel edge detection algorithm for finding edges.
4. Removing unimportant edges in the PIE (P Preliminary Edge Image) by selecting the non-edge points that can be removed and a new edge image can be allocated that followed by plotting the new points on the temporary edge image.

3.7 Image Segmentation

Image segmentation is a process of dividing an image into multiple segments to provide meaningful information and prepare it for the next analysis process. The process can be done by scanning every pixel in an image after labeling each pixel (Padmappriya and Sumalatha, 2018). To detect fire in the digital image, the technique will segment fire and separate it from a non-fire background (Poobalan and Liew, 2015). Since fire mostly contains yellow and orange colors and have higher brightness, thus, HSV and YCbCr color models can be used for the segmentation process to segment the flame from the background. For detecting color and brightness information, The HSV color model can be used for detecting information related to color and brightness. The YCbCr color model can be used for detecting information related to brightness due to the model's ability to distinguish bright images in a better way compared to other color models (Seebamrungsat et al., 2014). The input data can be either an image or a real-time video by selecting video frames as input that processed to be ready for generating an output with highlighting the fire location in the images that contain on and off (1, 0) pixels, where 1 means a segmented flame pixels and 0 means anon-flame pixels. The accuracy of the technique can be improved to avoid false detection like candles in the image or dress in orange color. To avoid the mismatch, the growth of fire can be monitored to improve segmentation process using additional techniques, including noise reduction algorithm (Seebamrungsat et al., 2014). Many other study have also used segmentation technique for separating fire from non-fire background in an image, e.g. by specifying the color range using ROI (Region of interest) (Poobalan and Liew, 2015).

4. Conclusion

Different image processing techniques can result promising outcome to detect fire in early stages used in different algorithms for fire detection. And the following subsections present the results of those color models. As illustrated in section 3.1.1, an algorithm has been developed by (Poobalan and Liew, 2015), to detect a fire in digital images by converting RGB image to HSI color model. Different sets of images were used as an input; the result of the technique is shown in figure 1. Different algorithm for fire detection and managing false alarms based on computer vision has been developed. Ford and Roberts (1998) has CIE L*a*b color space to identify fire pixels as shown in figure 2. As discussed in section 3.1.2, The developed model of fire color is tested with 10 different video sequences of different fire scenarios. The model gives a significant result of fire pixel classification with the rate of %99.88. Based on the lighting detection and analysis at which RGB and YCbCr color models were used for fire detection. The system input data consists of a webcam images that require extracting the frames from the. The main purpose of using RGB and YCbCr color models is to determine whether the flame is fire or not by detecting the difference between frames and calculate the fire growth. The main advantage of this system iseasy installation of CCTV cameras and a faster response time for fire detection (Nalawade, 2018). as demonstrated in section 3.1.3. Figure 3,4and,5 shows results of this method, respectively. In this study a set of 2 images and 3 videos were used for analysis. the system was successful in identifying fire in a short time to prevent deaths at time of fire outbreak. The system was also successful to discriminate fire with non-fire situations (Nalawade, 2018). Table.1 shows video sample cases of fire. Flame edge detection is considered as one of the very important task in image processing. Although there are numerous algorithms that have been developed for this purpose, this paper presents only two algorithms (Sobel, Novel) that are commonly used (Poobalan and Liew, 2015). As discussed in section 3.2.1, Sobel edge detection technique has been applied on the set of 4 images to detect the fire growth by calculating gradient intensity at a given pixel. The result of the technique is shown in Figure 6. The algorithm can successfully detect fire edges but cannot filter out unwanted or unrelated edges in the input images which can be counted as a limitation of this study. A Novel edge detection algorithm has been developed for the same purpose at which hundreds of flame images were processed for evaluation and analysis. The result was promising due to algorithm's ability to detect and identify flame edge in all images. The advantage of this algorithm is the ability of detecting continuous flame edges and ignore unwanted edges in the image thus making it easier to differentiate a flame from the background. The algorithm is also successful in extracting complex flame edges such as edges of turbulent diffusion and pool fire flames. (Qiu et al. 2011; Kalpana and Padmaa 2014). Fig. 7 shows the results of this algorithm in detecting flame edges. Image segmentation is one of the important aspects of image processing at which an image is divided into multiple segments for the sake of easy analyzing. As discussed in section 3.3, two different techniques have been used for color segmentation. In the first technique, a system for fire detection has used a web camera as an input which gets video from real life scenes of fire with another input source which is internet at which the scene could also contain a suspected fire scene. At first the color segmentation technique was used and tested on the videos for the sake of comparing frames of two fire locations for checking the growth of fire. In case of fire growth in more than 5 frames, the alarm will be activated and the feed on the input video will be counted as a fire. The system overview is shown in figure 8. As presented in section 3.3, total of 200 video samples were analyzed successfully,100 of which were for the case of burning objected in fire images, the other 100 were for the case of suspected fire scenes (See Bamrungsat et al., 2014). The system accuracy for detecting a fire in the images was 90.73% while it was 98.13% for the case of suspected fire images which were captured from the video input downloaded from internet. The system was applied to another 60 videos, 30 of them were related to fire scenes and the other 30 were related to non-fire scenes. The accuracy of the system for fire scenes in the first 30 videos was 100% with the ability to give fire warning within 2 minutes which is crucial for saving lives. While the accuracy of the system for the case of non-fire videos was 93.33% due to two different scenes which caused false alarm. One of the scenes was for a walking man wearing an orange shirt, while the other scene was for an orange colored siren blinking in a building. The second technique that has used RGB, HSI color models along with Sobel edge detection techniques for fire detection and segmentation. Total of 50 images have been analyzed in this study with the accuracy of 93.61% (Poobalan and Liew, 2015). The result of the technique is shown in the figure 9.

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تقنيه برمجه الصور لتحديد الحرائق

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المستخلص

اندلاع الحرائق في الغابات و البنايات تعتبر من احدى الطرق المتكررة التى تهدد البيئه فى حياة الإنسان والحيوان. لمنع التهديد الحرائق استخدمت عدة الطرق لتحديد الحرائق التى تتراوح بين الطرق التقليدية الى الطرق الحديثة. في هذا البحث تم مراجعة الطرق و تقنيات مختلفة لتحديد الحرائق وكذلك طرق مختلفة تم تطويرها بهدف تحديد المبكر للحرايق من خلال سيناريوهات مختلفة باستخدام تقنيات معالجه التصور. الطريقه الامثل بين هذه الطرق المستخدم، هى الطريقة المعتمدة على برمجه الصور. نماذج مختلفة من الالوان مثل CIE و HSI و RGB) **تم استخدامها مع خوارزميات عدة كمثال** (YCbCr و L * a * b) **و اخيرا تم مناقشة تقنيات تقسيم** (Novel edge Detection و Sobel). **الالوان في هذا البحث. كل الطرق المذكورة في هذا البحث اثبتت دقتها في تحديد الحرائق و اللهب في الصور الرقمية المنظمه حسب الوقت، و التى بدورها لها تأثير كبير في المحافظة على الحياة وتقليل الخسائر الأرواح.**

الكلمات المفتاحية:

كشف الحرائق ، معالجة الصور ، نموذج الألوان ، كشف الحواف ، تجزئة الصورة.

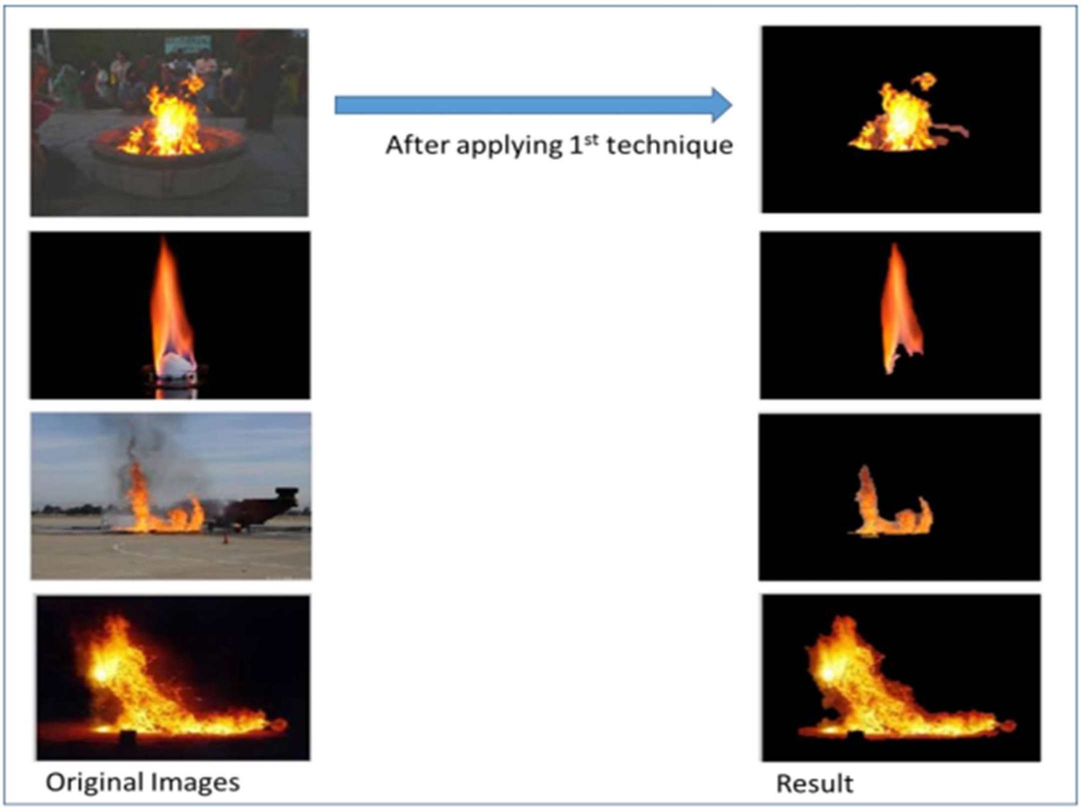

Figure 1: Result of RGB to HSI color model conversion on set of fire images (Poobalan and Liew, 2015).

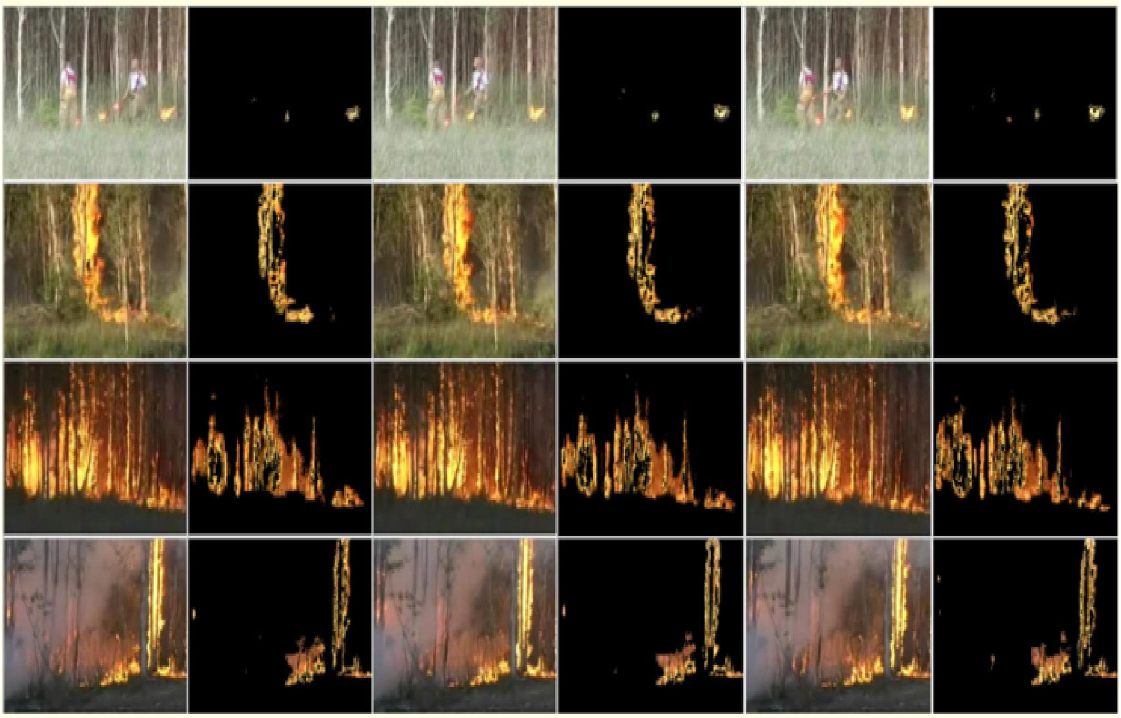

Figure 2: Result of CIE L*a*b color model on different sample fire videos (Ford and Roberts,1998).

Figure 3 : Shows the captured RGB image at which the video is converted to frames (Nalawade, 2018).

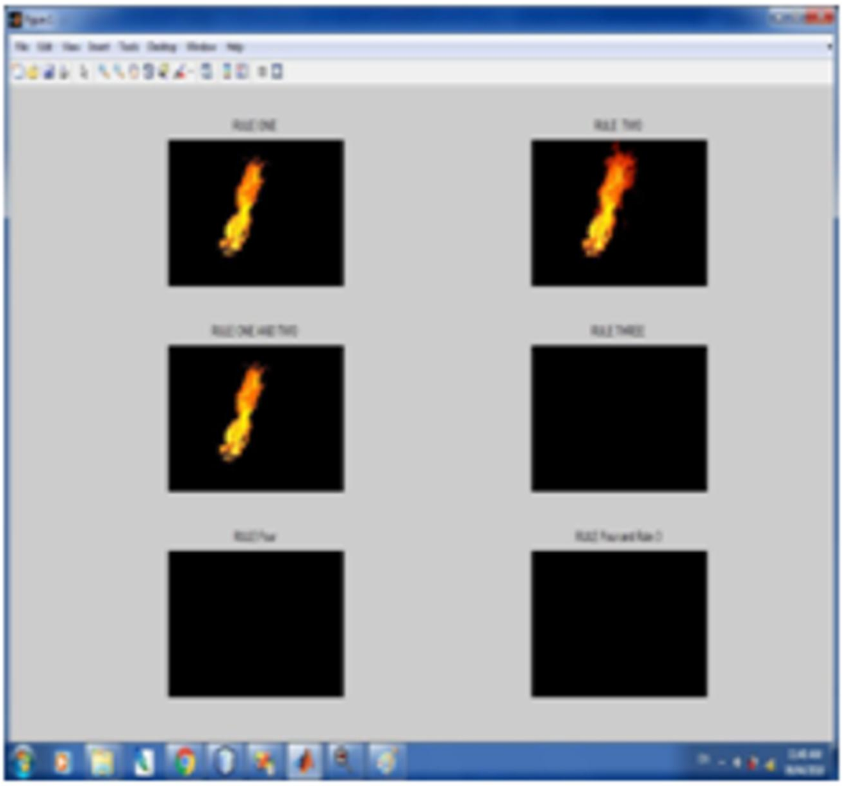

Figure 4: shows the use of YCbCr rules, the difference

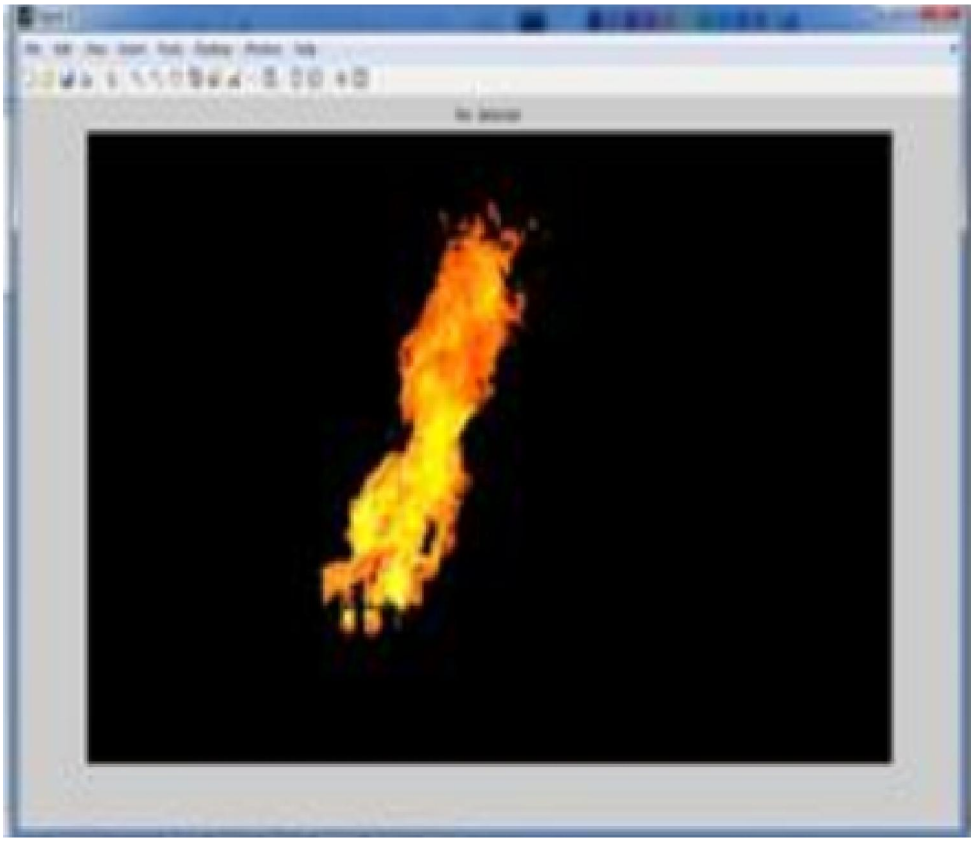

Figure 5: shows a successful fire detection in the frame is calculated. Nalawade (2018).

Table 1: Sample Fire Video Cases (Nalawade, 2018)

Sr No.	Test Description (Input)	Expected output	Actual Output	Result
1	Incorrect fire image	Not a Fire	Fire not detected	Pass
2	Correct fire image	Not a fire (just an image)	Fire not detected	Pass
3	Video containing candle fire	Not the fire as flame is constant	Fire not detected	Pass
4	Video containing Matchstick fire	Not the fire as flame is constant	Fire not detected warning a	Pass
5	video having fire	Fire detected	Fire detected	Pass

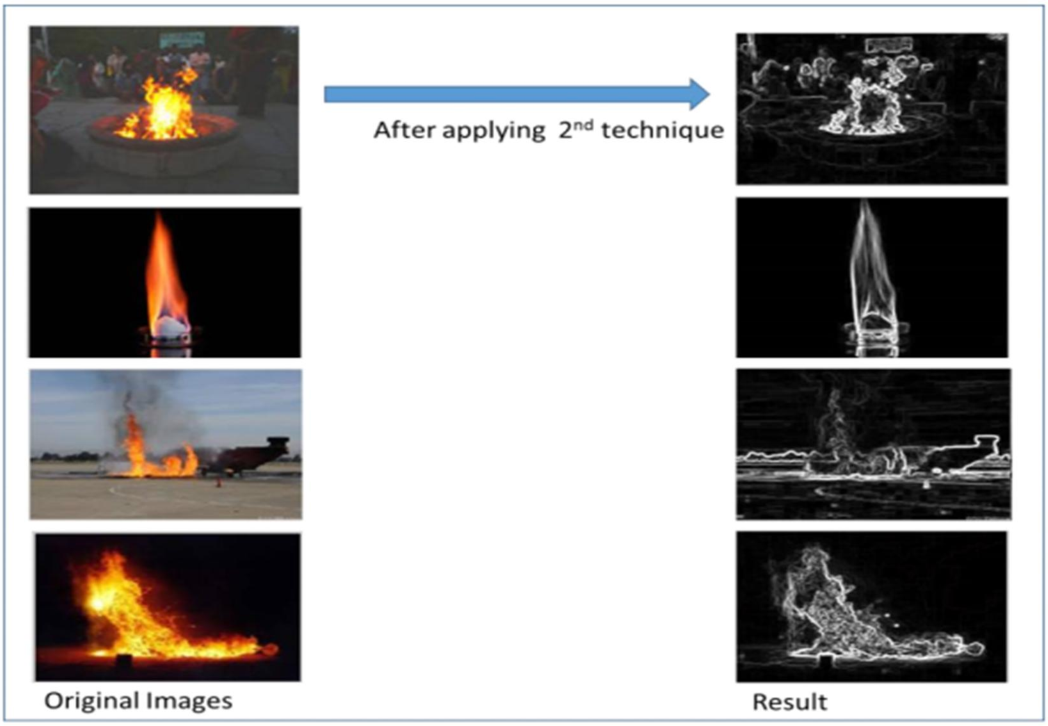

Figure 6: Sample fire images after applying Sobleedge detection technique (Poobalan and Liew, 2015).

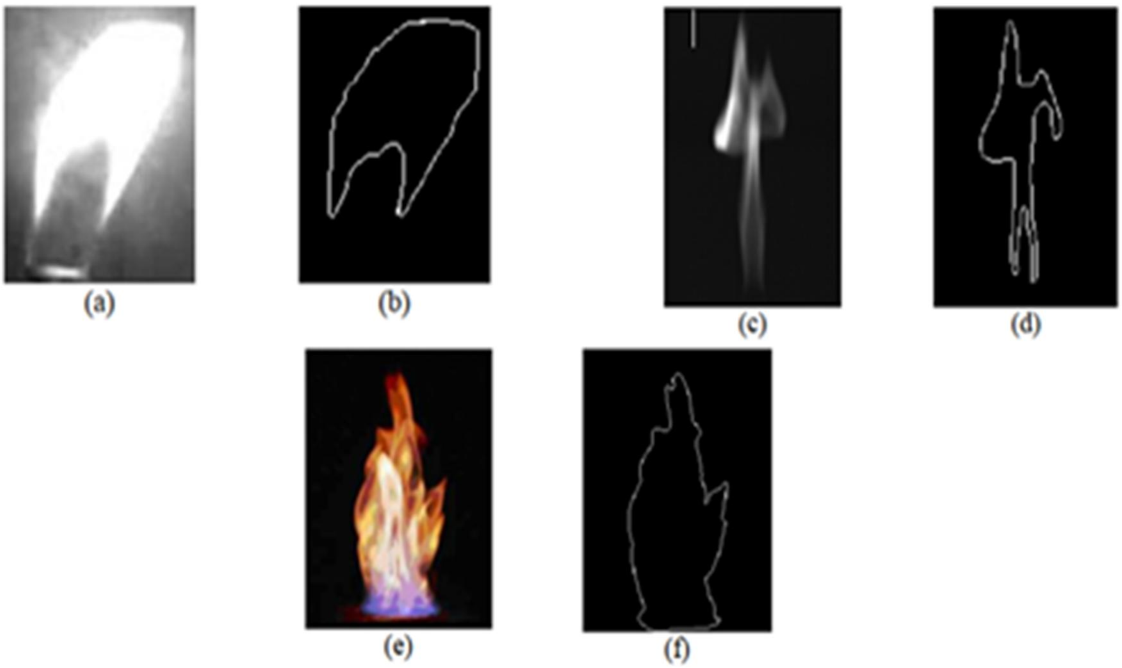

Figure 7: Result of flame edge detection using Novel algorithm Qiu et al. (2011).

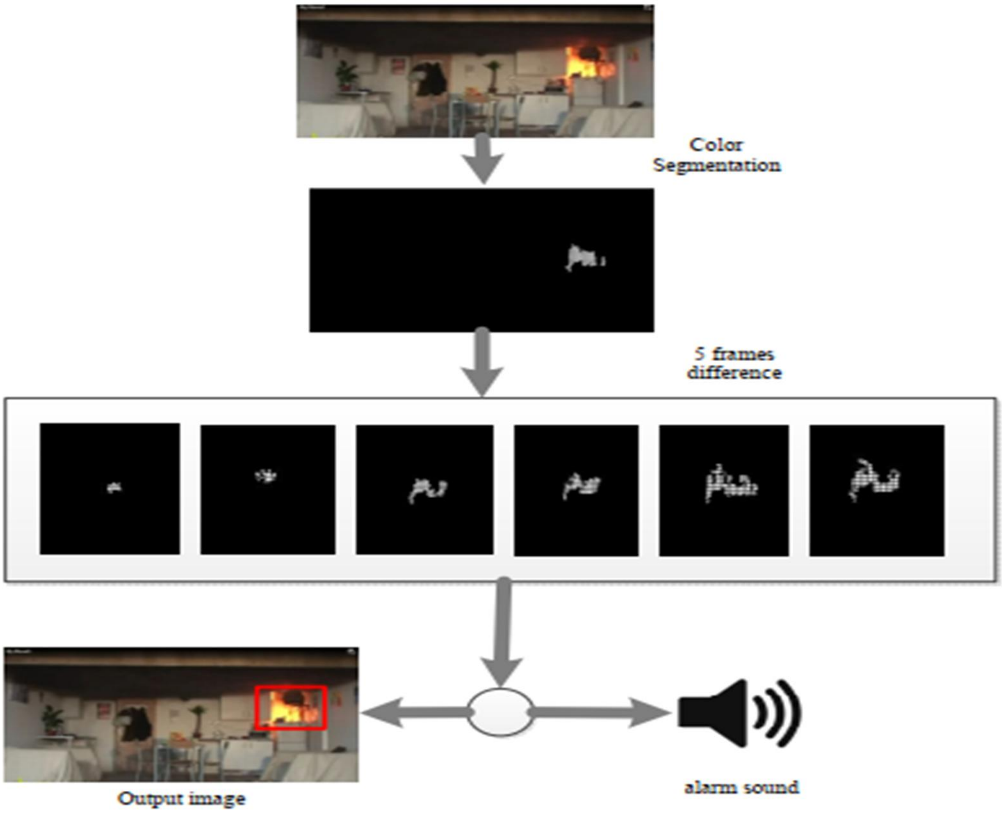

Figure 8: Overview of the developed system (Seebamrungsat et al., 2014).

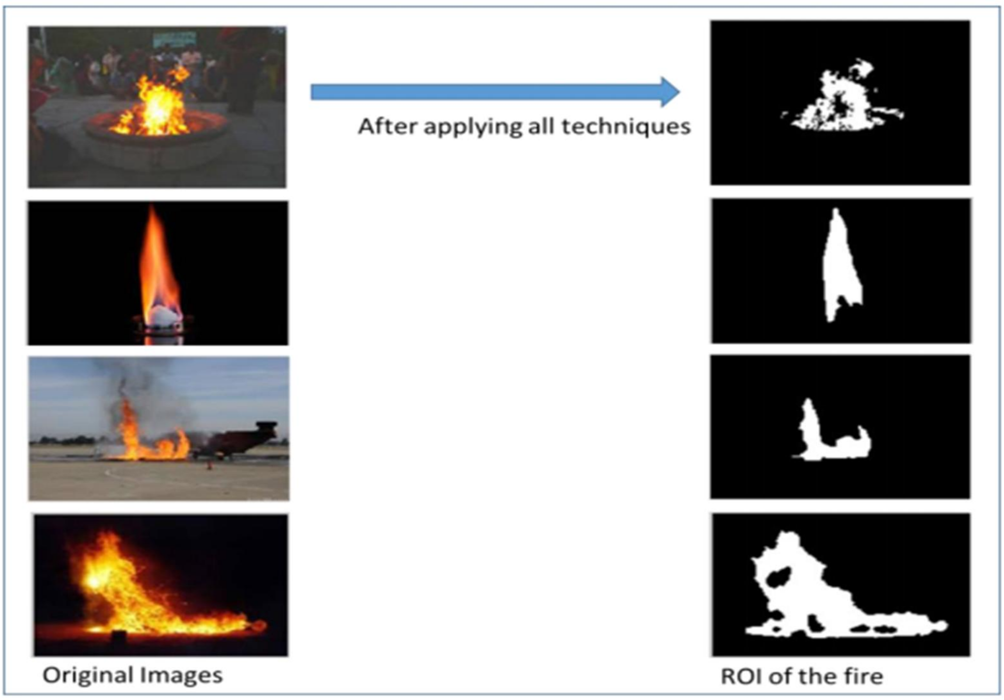

Figure 9: Implementation of segmentation technique with the results of Sobel algorithm and RGB to HSI olor model conversion m