Detection of fire using image processing techniques with LUV color space

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***Abstract*— Vision based fire detection system have recently gained popularity as compared to traditional fire detection system based on sensors. The popularity and need of video surveillance at residential, Industrial, public and business locations have supported the widespread use of vision based fire detection system. The colour of fire is the basic technique for identification of fire in an image. However, the colour of fire varies from red, orange, yellow to white. Also, there are non-fire objects with fire-like colour. In order to improve the accuracy of fire detection system, colour detection is combined with various other techniques. Edge detection, motion detection ,area covered by flames, existence of smoke, growth of fire and background segmentation are some techniques which are combined by various researchers and used to correctly classify the fire images and fire-like non fire images in a video. There are also various thresholds that are used to differentiate fire in any frame. These thresholds need to be adjusted based on the type of area and its brightness level. Also, the difference in the subsequent frames and area covered by the flames supports the existence of fire if it is greater than the threshold. This paper presents the comparative analysis of five recent vision based fire detection system. These fire detection systems are based on flame colour detection combined with other features such as motion and area of frame. The fire detection system based on LUV colour space and hybrid transforms is proposed.**

Keywords—Fire detection, flame color detection, flame area and motion, flickering, flame texture, Segmentation, LUV Color space, image processing, Smoke Detection

I. INTRODUCTION

Occurrence of fire causes severe threat to life and property. Fire detection system detects the occurrence of fire and alerts the occupants by raising the alarm. Traditional fire detection systems are based on sensors that rely on heat, pressure, smoke and temperature conditions works slower than vision based fire detection system which works on the detection of light [2]. Traditional fire detection system has high implementation cost and response time. Sensor based fire detection requires more number of sensors to cover a large area and also waits for some conditions to trigger the sensors [1].

The fire detection system using image processing techniques usually works in 3 steps: Capturing the image using digital camera, image analysis and enhancement to detect existence of fire, Output is the analyzed image that generates alarm in case of existence of fire. The main issue with fire detection system is the false alarm rate. False alarm may be generated when a fire like object comes in the video frame and the system classify the object as fire due to the pixel value that matches with the fire pixel values.

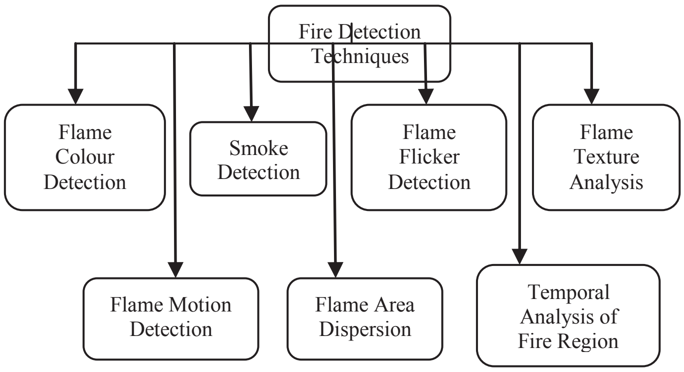

Fig 1. Fire Detection Techniques

To improve the efficiency of the vision based intelligent fire detection, system flame and smoke colour detection was combined with edge, motion, area and texture analysis [1,2,3,6,7]. Fig 1 shows the available fire detection techniques in literature. Below is the description for each technique.

Fire detection based on Flame colour Detection [1,5,9]

The flame detection is based on detection the color of the flame. Fire pixels have a higher intensity of red component.

a. In RGB color model
   R Intensity > G Intensity > B Intensity
   R Intensity > $R_{Threshold}$
b. In HSV Color model
   S > (255-R)*S Threshold/R Threshold
c. In YCbCr color model

It compares the Luminance, Blue and Red component chrominance of any pixel with their mean values to identify the presence of fire pixels.

Fire detection based on flame motion Detection [2,3,7]

Flame motion detection detects the occurrence of motion in flame by comparing consecutives frames in the fire videos and analyzing the number of fire pixels identified along with their position in the compared frames. There are basically three methods for motion detection:

a. Frame/Background Subtraction: The difference between two consecutive frames of the video is calculated [8].
b. Background Registration: Pixels of past several frames that are not changing or moving are identified as the background.
c. Moving Pixel Detection: The difference between the background and difference between frames are used to identify the moving pixel in binary format image.

Fire detection based on fire intensity and growth [2,8]

Fire has a tendency to grow; the motion of the flame as well as the area covered by fire will differ with time. The frames captured at different time stamp are compared in order to identify the growth of fire. The frame difference is calculated and compared with threshold to determine the existence of fire. Motion and edge detection are also used to compare the frames.

Fire detection using flame texture and Smoke Detection [4,5,10]

The texture, shape, change in area occupied by flames and presence of smoke is analyzed in order to decide the existence of fire. The temperature and brightness of flame is highest at the edges and is lowest at the centre. These features can be used to separate true fire region and fire like objects in the area of interest. The intensities of R, G and B component are similar in case of smoke. Also, Smoke is a low frequency signal while the smoke edges are high frequency signals that helps in identifying the smoke region. The flickering nature of flame is also an important feature.

II. LITERATURE SURVEY

Fire detection system based on image processing and video processing techniques are present in research works. The fire detection that are based on flame color detection and uses other features of flame and smoke are discussed in this section. [Kumarguru Poobalan and Siau-Chuin Liew][1], designed an algorithm that combines the result of color and edge detection to segment the candidate fire region. Fig 2 shows the block diagram of the implemented technique. The algorithm uses the RGB color model to detect the flame color by the intensity of component R. The growth of fire is detected using Sobel edge detection. The result from color detection and sobel edge detection are combined using the segmentation technique to identify the region of fire. The values of the R, G, and B channel are analyzed for every pixel to detect the existence of fire. The fire pixels satisfied the below two conditions.

Condition 1: $R > G > B$

Condition 2: $R > R_{Threshold}$

If both the above conditions are satisfied, the pixels are identified to be fire pixels. The result is then converted to HSI colour model. Sobel edge detection using a 3*3 convolution mask is used to detect the edges in the image. Both vertical and horizontal mask are used for edge detection. This is used for detecting the growth of fire. Sobel mask is applied on the original image captured by the camera. The connected edges are detected by applying both horizontal and vertical mask. Thus, image with all the detected edges is obtained. The resultant image from the fire colour detection and edge detection are combined together to obtain the fire region in the original image. Segmentation based on threshold is used to segment the fire region from the non fire background. This gives the region of interest of fire.

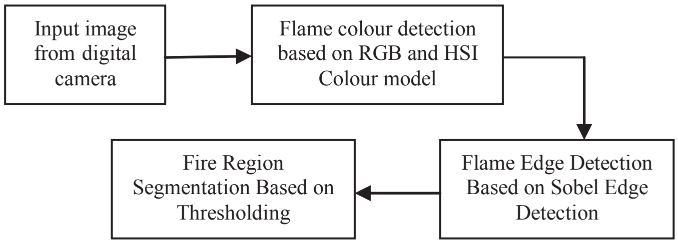

Fig 2. Fire Detection System by Kumarguru et al. [1]

[Jareerat Seebamrungsat et al.] [2], designed an algorithm that predicts the existence of fire using color based detection. The algorithm utilizes the methods of frame differencing to identify the growth of fire over the next five frames. If fire pixels tend to grow over a certain threshold then the existence of fire is confirmed and the alarm is generated.

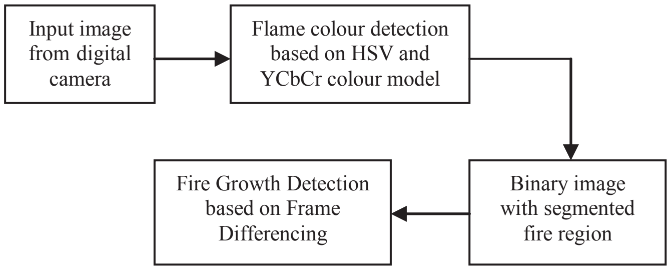

Fig 3. Fire Detection System by Jareerat et al. [2]

Fig 3 shows the block diagram of the implemented technique. Fire images are very bright that are composed of red, orange and yellow colors. The HSV and YCbCr color models can detect the fire by separating these fire-like colors from the background. The HSV and YCbCr model extracts information related to the color and brightness of fire respectively. If the Pixel at any spatial location(x, y), satisfies the condition of both HSV and YCbCr model it is identified as fire pixel and its pixel value is replaced with one. Rest all the pixel values are replaced with zero. Hence, after applying color detection we obtain a binary image of the original image where the fire pixels have value 1 and rest of the pixels are made zero and thus, segmenting the fire pixels from its background. The opening algorithm is applied on the binary image for noise reduction. To avoid the risk of false detection in cases such as someone wearing an orange color t-shirt or a lighted candle or matchstick comes in front of the camera the method of frame differencing is used to detect the growth of fire. First, the two consecutive fire frames are selected and White pixels are counted. Then, the difference between the numbers of white pixels in each image is calculated. The difference of white pixels between the two frames should be positive and above threshold to detect fire growth. 13% of data difference from the base images was selected as threshold. This white pixel difference is calculated consecutively 5 times and it should satisfy the threshold condition.

[Gaurav yadav et al.] [3], designed a novel algorithm that performs the job of identification of gray scale pixels around the flame for fire detection. The grey scale pixels are obtained from the smoke generated around the fire.

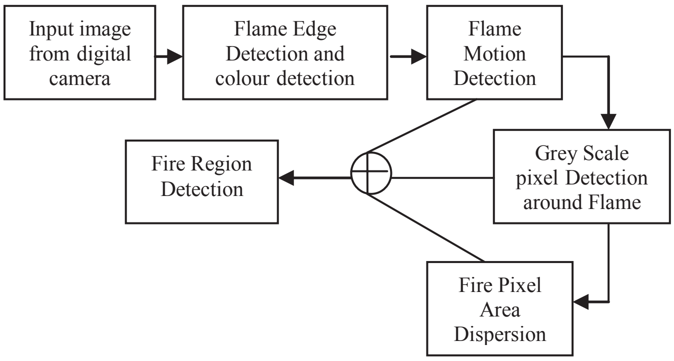

Fig 4. Fire Detection System by Gaurav et al. [3]

Fig 4 shows the block diagram of the implemented technique. This paper combines the existing fire technique such as color difference, flame motion detection and flame edge detection and optimizes the fire detection by applying different combinations of these techniques as per the requirement of different sensitive areas. The algorithm captures the video with ordinary camera and extracts each frame for fire detection. The first technique applied on the extracted frame is edge detection that detects the color variance in the image. The intensity difference in the image is compared with the global intensity threshold and provides an image with black and white color space. The high intensity area is covered with white color and low intensity area is covered with black color. The output provided by edge detection is the shape of the flame. The original image is then analyzed for fire color detection by utilizing the RGB color model, the value of RGB component and the ratio between R, G, and B components. Color detection on original image gives the corresponding binary image with the detected fire pixel area. There are 3 different techniques namely Motion detection, Gray-scale pixel detection and area dispersion.

1. Motion detector detects any occurrences of movement in the video by comparing two sequential frames. Motion is detected if the fire pixel values shows difference in both the frames.

2. Gray scale pixel detection is used to detect the existence of smoke in the region which is half above the fire region. The properties and values of R, G, and B components are used to detect the existence of smoke.

3. Area dispersion method is used to detect dispersion of fire pixel area in the sequential frames.

The Output from the Motion detection, Gray-scale pixel detection and area dispersion is given to the operator that performs the logical operation on these results to give the output for fire detection.

[A. E. Gunawaardena et al.] [4], designed a novel image segmentation technique along with YCbCr color space to determine the existence of fire. In addition to motion and color detection the fire region is analyzed for flame flicker detection to confirm the existence of fire.

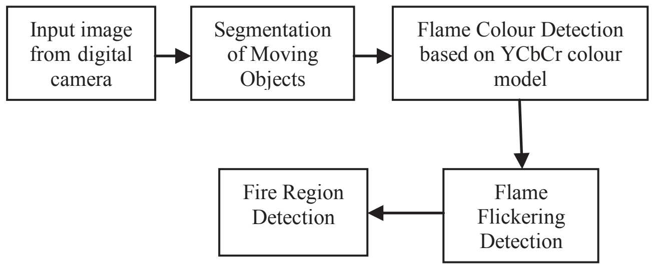

Fig 5. Fire Detection System by Gunawaardena et al. [4]

Fig 5 shows the block diagram of the implemented technique. The frames are extracted from the video and foreground moving object is segmented from the background using adaptive background subtraction method. The pre-processing is done on the frames to reduce the camera noise by using liner filters. Background modeling is done by comparing two frames at time t-1 and t to calculate the absolute difference. A pixel is considered to be moving if difference in the pixel intensity value at spatial location(x, y) is greater than the motion threshold value. YCbCr color space is used for the detection of fire color in the segmented frames. The relation between the Luminance, Blue Chrominance, Red Chrominance and the difference between the chrominance values are compared with threshold to detect the existence of fire pixels. The value of threshold depends and needs to be set according to the fire like object under consideration. Morphological operation namely closing is applied on the input image from color detection to fill the tiny holes and to smooth the boundaries for highlighting the fire region. The extracted pixels are overlaid into the original image to produce the output image with pixels at original image. To remove the fire like pixels in the candidate fire region from motion and color detection, the concept of fire flickering is applied. The boundary pixel in the candidate fire region shows transition from background color to flame color due to the flickering nature of fire and was used to calculate the spatial mean variation of consecutive frames which is compared to the threshold to confirm a pixel as fire pixel and detect the existence of fire.

[C. Emmy Prema1 et al.] [5], designed an algorithm using YCbCr color model that separates luminance from chrominance for the separation of fire flame pixels. It also separates high temperature fire centre pixels with the support of statistical parameters such as mean and standard deviation. It uses four rules based on YCbCr model to classify the fire region and high temperature fire centre region.

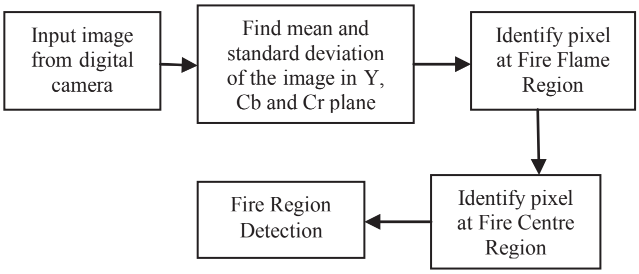

Fig 6. Fire Detection System by C. Emmy Prema1 et al. [5]

Fig 6 shows the block diagram of the implemented technique. The RGB input image is converted into YCbCr color model which is effective in detecting the brightness and has less complexity. YCbCr model effectively separate intensity and chrominance and gives strong representation of fire color. Y, Cb and Cr values are used to calculate the mean and standard deviation. There are four rules based on the relation between a pixel at any spatial location(x, y) which are used to classify the fire pixels based on the texture and properties as fire edge and fire centre region. The fire region tends to show the existence of red color at fire pixels and the fire centre region is white in color.

These four rules are combined and each pixel is analyzed based on the rules combination. Each pixel is classified as fire flame region, fire centre region and non fire pixel. A pixel is classified as fire flame pixel if it satisfies Rule I and Rule II. However a pixel is classified as fire centre pixel if it satisfies Rule III and Rule IV. Rule I states that any pixel belong to the flame area region, if the value of Y component is greater than the value of Cb component. Rule II states that any pixel belongs to the flame area region, if it satisfies rule I and the value of Y component is greater than Y mean and value of Cr component is greater than Cr mean. Rule III states that any pixel belongs to fire centre region, if Cb component is greater than Y component and Y component is greater than Cr component. Rule IV states that any pixel belongs to fire centre region, if it satisfies rule III and value of Cr component is less than the standard deviation of Cr. To get the true fire region, fire flame region and fire centre region must be detected. Hence a pixel which satisfies either Rule I & Rule II or Rule III and Rule IV appears in true fire region. The true fire image can be obtained by adding the two images, one of which is obtained by satisfying Rule I and Rule II another by satisfying Rule III and Rule IV.

III. COMPARITIVE ANALYSIS

The techniques in all the above discussed papers use flame color detection as the basis for identification of fire. The accuracy of the system is in terms of false alarm rate, performance; data set and future work are considered as the basis for comparison. The algorithm in [1] was tested on 50 images. The accuracy of the system i.e. the ability of the system to detect the region of interest was 93.6%. The efficiency of the system is 80.64%. The accuracy of the algorithm shows that the algorithm works significantly well in case of a real fire outbreak. However the efficiency of the algorithm which includes the instances where a non fire image classified as fire and a fire image is classified as non fire needs to be improved for which motion of fire may be considered. The algorithm in [2] was experimented on 30 fire video files and 30 non fire video files. The accuracy for fire detection in case of fire videos file was 100% and the fire notification was given within two minutes. Non fire video files show the accuracy of 93.33% where two non fire videos sequence was detected as fire and caused false alarm. To reduce the false alarm rate the shape, size and intensity of the object approaching the camera can be analyzed. The algorithm in [3] was implemented on images from two videos and provides the system performance of 92.31% and reduced the false alarm rate compared to the situation where only one or two techniques are used. However, we need a parameter to decide the optimization level based on the sensitivity of area. The experiment on 10 images are performed by [4] gives an excellent accuracy of 100%. But the limitation is that the experiments were performed in a similar condition and all the images were taken from the same area and illumination level for which the threshold was constant and hence provided an accuracy of 100% Smoke detection can also be combined with temporal analysis of frames. The algorithm in [5] was tested on three set of images. First set contain fire. Second set contain fire like regions. The third set contain fire centre like regions. The proposed system achieves 99.4% fire detection rate and 12% false alarm rate. Computational complexity of the proposed system is less; hence, it can be used for real time forest fire detection and provides high accuracy of true fire detection. The performance of the system can further improved by considering the motion characteristics of fire flame like fire movement. Geometric parameters of the flame such as position, rate of spread can also be utilized to obtain better results.

IV. PROPOSED SYSTEM

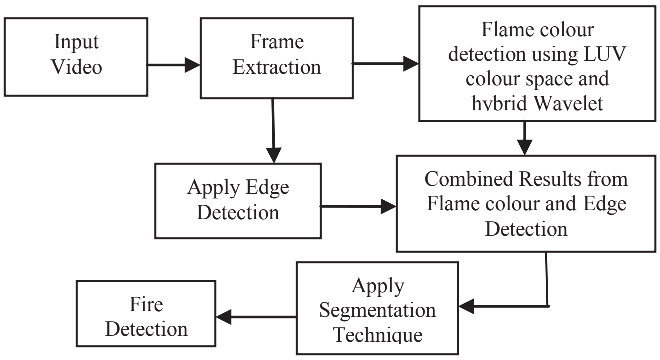

Figure 7. Proposed Fire Detection System

The proposed fire detection system shown in fig 4.1 reads a captured video and extracts the frame. Each frame is analyzed for the presence of fire. Fire is identified by the presence of fire pixels in the image. Fire pixels are identified by using the features of LUV color space and hybrid transforms[11]. Once the flame color confirms the existence of fire, edge detection techniques are applied on the original image to obtain the edges of the image. The result from flame color detection and edge detection are combined. Image segmentation technique is applied on the combined resultant image to segment the fire region from the background display the result of fire detection. Most of the papers use RGB, HSV and YCbCr color space for identifying the flame region. LUV color space along with hybrid transforms can be used to obtain better results.

V. CONCLUSION

The vision based fire detection system captures the images through digital camera and analyzes each frame for the presence of fire pixels based on flame color, area, and motion and texture analysis. However, smoke which appears even before the flame can be considered as a basis to trigger the fire detection system. Presence of smoke and appearance of flame can be combined together to reduce the response time of the system. Motion of flame and area covered by the flame when combined with the color detection improves the accuracy of the system. The texture of the flame i.e. its color and brightness at the edges and centre can be exploited to improve the performance of the system. One of the most prominent and less exploited characteristics of flame is the flickering of frames. Flickering of flames when considered provided very good results and it can be used with flame color detection and motion detection to reduce the false alarm rate in case of a fire like non fire image is captured by the camera. The detection methods can be optimized as per the nature of area covered by the detection system and also different techniques for fire detection can be combined together to reduce the false alarm rate and improve the response time. RGB and YCbCr are common color models for flame color detection. We can also implement LUV color space to obtain better results.

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