Optimal Fire Detection Using Image Processing

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Abstract- Flame detection and classification of flames is challenging work in the field of image processing. Use of image processing instead of sensors helps detection of fire in more accurate and quick manner. Thus this paper introduces a optimal approach for detection of fire using image processing technology which enables fire detection at the earliest in order to reduce life and property loss. The proposed system uses color segmentation model for detecting fire with reference to HSV and YCbCr color models. Also, density of fire growth is detected by the frame difference technique.

Keywords*—fire detection; color segmentation; image processing*

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I. Introduction

Fire causes human life and property loss at high level, thus detecting fire early is very necessary. Many sensors like Fire detectors, smoke detectors and temperature detectors are readily available in market & are widely used to protect property and give warning alarms. Old Traditional methods of using sensor based methods have many drawbacks: they have delay in transmission; they are generally applicable for indoor regions and can't be implemented for external regions to monitor a large area. While fire detecting scheme based on vision, has many advantages: a large amount of area can be monitored; detecting exact location of the fire can be done and can be integrated along with the surveillance camera. In order to initiate earlier detection of fire, and to prevent the spread of the fire, we propose a fire detection system based on light color detection. This system uses various color models with given conditions to differentiate color. The system will trigger an alarm and generate visual images of the fire as a red box superimposed over the fire image. There are many advantages in replacing conventional fire detection techniques with computer vision-based systems.

This analysis is usually based on two figures of merit; shape of the region and the minimal changes of the region. The performance of fire detection depends highly on flame pixel classifier performance which prepares seed areas on which the rest of the system executes. The classification of flame pixel is thus important to have a very high rate of detection and also low false alarm rate. The flame pixel classification scheme can be considered both in color video sequences and gray scale.

The National Fire Protection Association Standard has defined various classes of fires out of which the proposed

system will focus on detecting class A and class C objects. class A include objects such as paper, wood, rubber ,cloth or plastic and class C objects include electrical objects such as outlets, power boards, electric motors and so on. Both fire classes have almost similar characteristics of fire flame. The input given to the system is real time video generated from any video camera. The system will highlight the fire area by including that area in a red colour box.

This paper is organized into five sections: Section I provides introduction of the system; Section II describes related work and reviews of previous works; Section III presents proposed system in detail; Section IV provides implementation result ; Section V is the meant for Conclusion.

II. Related Work

There are many fire detection systems which are based on video imaging that are implemented in different research papers, with excluding some of detection which uses video sequencing. The fire detection research is generally based on video sequences and is divided into two following categories: fire flame detection and fire smoke detection [1]. Proposed system connected to fire flame detection technique, therefore it is discussed in this section.

To detect fire complete area using colors of flame is described in [2-4]. Wenhao and Hong [2] used fire flame color in which object of fire was extracted using iterative adaptive threshold technique as a form of analysis to detect fire flame. Juan et al. [3] proposed visual analysis and frame extraction of fire flame colors in the enhanced RGB-color space. YCbCr colors space to differentiate luminance from chrominance was used by Celik and Demirel [4] . There is possibility of high false detection only at the time when color characteristics have been used. There is a study regarding shape of flame and its characteristics [1]. Xiaoxiao and Junying [5] intended a detection of fire by finding for snon blunt corners on the line of contour of multi-layer contours which are closed of flame pictures. Threshold values and the dynamic contour of flames are used to detect flame characteristics Yan et al. [6] used. It is

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likely to retrieve low accurate visual raw data as fire flames need to have so many various patterns within a video. There is an exclusive study using highly accurate information on the fire characteristics [1]. Rong et al. [7] proposed a color based fire detection system, and fire's pattern characteristics. This uses the color model generic and independent geometrical component analysis model, the cumulative independent component analysis model, and BP neural network i.e. based on multi-feature for fire shapes. Frame differences, median filters are used in reducing the noise process, and Bayesian classifier in a recognition process to detect fire flame was implemented by Lei and Liu [8]. Celik [9] proposed algorithm and divided it into two components modelling of fire color and motion detection. The modelling of color element uses CIE L*a*b* color space. The flame movement detection element implements frame/background subtraction, background registration, and moving pixel detection.

Proposed system uses simple algorithms based on color conditions and fire growth checking. It is a real/run time processing method.

III. Proposed System

A. *Proposed System Overview*

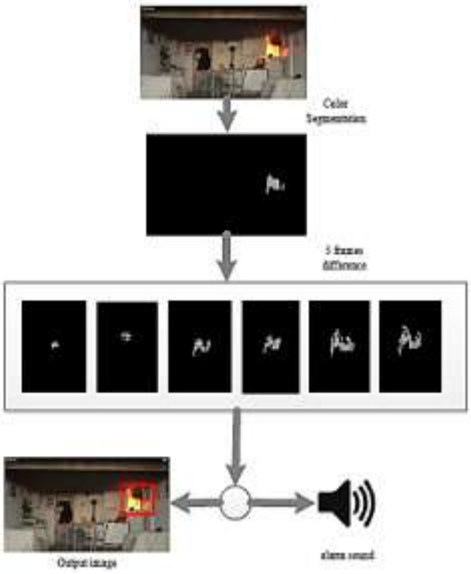

Fig.1 System Overview of the Proposed System

The proposed system consists of three phase which are explained below and shown in the Fig. 1:
Algorithm:
The working algorithm is shown in fig 2.

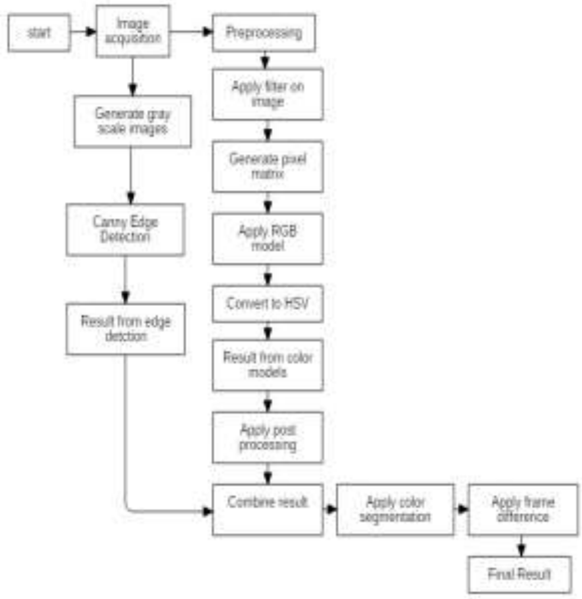

Fig.2 working algorithm of the Proposed System

Step 1: In the first step, input video will be collected from data source such as web camera and video will be converted into sequences of images i.e. frames for further evaluation so that the process of further detection can been started.
Step 2: In Second step images are converted to gray scale and canny edge detection technique is implemented in order to get edge detection on the generated images.
Step 3: In the Third step, images are converted to RGB color model which in turn are converted to HSV Color model and YCbCr color model.
Step 4: Results from step 2 and step 3 are combined and Colour segmentation technique is applied on each frame in order to separate expected fire from its background. Fire location are detected with help of color. HSV and YCbCr color models are used in this process.
Step 5: If fire pixel is detected during color segmentation then fire growth is checked in the next step using frame difference technique.
Step 6: In this method two consecutive frames are compared and the alarm will be triggered if fire pixels increases over a span of considerable frames. If fire growth is detected then the fire pixel area will be superimposed by the red box. Frame differences is used to reduces false detection of fire and improve accuracy of overall model.

B. *Gaussian Filtering*

The Gaussian function is used in various research areas:
– It defines a probability distribution for noise or data.
– It is a smoothing operator.
– It is used in mathematics.
The Gaussian function has important properties
Which are verified with respect to its integral:

$$I = \int_{-\infty}^{\infty} \exp(-x^2)dx = \sqrt{\pi} \qquad \text{Eqn. 1}$$

The Gaussian filter works uses the 2D distribution as a point-spread function. This is achieved by convolving the 2D Gaussian distribution function with the image. We need to produce a discrete approximation to the Gaussian function. Gaussian distribution is non-zero everywhere. Fortunately the distribution has approached very close to zero at about three standard deviations from the mean. 99% of the distribution is within 3 standard deviations. This means we can normally limit the kernel size to contain only values. This means we can normally limit the kernel size to contain only values within three standard deviations of the mean.

C. Color Segmentation

Colour segmentation involves differentiating fire parts from its background [10]. After analysing several images of fire it is deduced that fire consists of red, orange and yellow and have high level of illumination. Thus to identify fire pixels HSV and YCbCr are potential models to be used. Hue, Saturation, Value or HSV is a color model that describes colors (hue or tint) in with respect to their shade (saturation or amount of gray) and their brightness (value or luminance). YCbCr color model has the ability to distinguish luminance information from chrominance information more effectively thus it is used in our model.

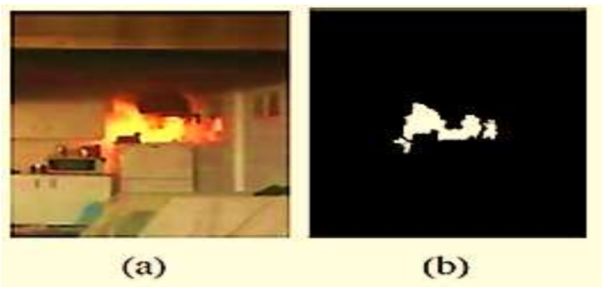

Fig.3 Color Segmentation Samples

To detect fire flame, the conditions are formed as follows in Eqn. 2[10]:

$$f(x,y)=\begin{cases} 1 & if\,((0.02 < H(x,y) < 0.30) \text{ and } \\ & (0.20 < S(x,y) < 1.00) \text{ and } \\ & (0.98 < V(x,y) < 1.00) \text{ and } \\ & (Y(x,y) >= Ymean) \text{ and } \\ & (Cb(x,y) <= Cb\ mean) \text{ and } \\ & (Cr(x,y) >= Cr\ mean)) \\ 0 & otherwise \end{cases}$$

Eqn. 2

where H(x, y) is hue, , S(x, y) saturation, and V(x, y) is intensity value at the spatial location (x, y) respectively. Y(x, y), Cb(x, y), Cr(x, y) are luminance, red component, and blue component of the spatial location say (x, y) respectively. Y_mean, Cb_mean, and Cr_mean are the mean values of luminance, blue and red components, respectively. Each frame of the video input is processed and above mentioned conditions are checked in order to obtain output fire images.

Each pixel of the fire location images contains one of these two values either 1 or 0. The pixel value 1 means the fire pixel. The pixel value 0 means the non-fire pixel. Fig shows examples of input and output images from the developed segmentation technique. Fig. 3(a) is the example of input video frame. Fig. 3(b) is the corresponding fire location image output. There are two colors, white and black, in Fig. 3(b). white color depicts the pixel value 1 and black color depicts the pixel value 0. Moreover, it can be seen from Fig. 3(b) that the white area indicates the fire location corresponding to Fig. 3(a).

D. Frame difference

Frame difference is one of the well-known and efficient way where the computer software examine the difference within two frames of video [10]. So there the developed segmentation fashion can strongly discern flames of fire in real-time captured fire video sequences as well as categorized video sequences. Considering for first case when there is no movement in frames then the difference within two images would show a black binary output image, and also show that there is no difference in single pixel. Moving to the second case if a movement is found in the frame then binary image of difference within the two consecutive frame shows motion which have white color and where there is no change in frames of fire then it shows black color. Although, there is possibility for a fault detection. The reason is that there are burning night light, lighted matchsticks, orange outfits, or many more different objects with shining orange color in the video sequences, giving much bright light.

First, a noise reduction algorithm such as Gaussian Filter is applied to reduce the possible noise that can cause false detection. Then, fire growth is checked, first of all, the two consecutive fire location images are selected and white pixels in each image are counted. Then, the difference between the numbers of white pixels in each image is calculated using following formula:

$$\text{difference count} = N_1\text{-}N_2$$

Eqn. 3

where N_1 is number of white pixels in the next image and N_2 is number of white pixels in the base image. The difference count between the two frames should be greater than zero and large enough in order to check fire growth. Moreover, five-time fire growth between successively consecutive frames will be checked in order to insure that it is an actual fire. If all the above conditions are satisfied, the system will activate the alarm sound and provides image notification by superimposed red box at fire flame in the video sequences as shown in the Fig. 4.

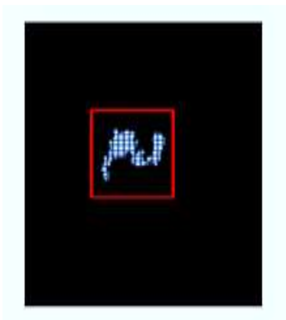

Fig 4. The superimposed red box on fire in video sequences

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IV. Implementation Results

Following steps are carried out on frames to obtain the result

Step 1**:**

Condition1: R > Rth

Condition2: R > G > B.

Where Rth is the Red color threshold value for fire.

Step 2:

When the image is converted from RGB to YCbCr color space. Then intensity and chrominance is easily discriminated. YCbCr color space can be easily model as following for the fire:

Y = 16 + R * 65.481+ G * 128.553 + B * 24.996
Cb= 128 + R * -37.797 -G * 74.203 + B * 112.0
Cr = 128 +R * 112.00 + G * -93.7864 + B * -18.214

In YCbCr color space, Y′ is the luma component (the "black and white" or achromatic portion of the image) and Cb and Cr are the blue-difference and red-difference chrominance components, will be chosen intentionally because of its ability to separate illumination information from chrominance more effectively than the other color spaces.

Step 3:

In step 3, YCbCr color space is considered and analysis is performed, for a fire pixel Y(x, y) >= Cr(x, y) >= Cb(x, y) is satisfied, whereas non-fire pixel don't satisfy this condition, Assumption made— (x, y) is spatial location of a fire pixel. Such system can be useful for detecting forest fires' where we can't put sensors at each location. So we can summarize overall relation between Y(x,y), Cb(x, y) and Cr(x, y) as follows:

Y(x, y) >= Cr(x, y) >= Cb(x, y)

Now, we can have some rules for fire detection:

Rule1: R1(x,y) = 1 , if ((R(x,y) > G(x,y)) &&(G(x,y) > B(x,y)))
0 , otherwise

Rule2: R2(x,y) = 1 , if (R(x,y) > 190) && (G(x,y) >100) && (B(x,y) < 140)
0 , otherwise

Rule3: R3(x,y) = 1 ,if Y(x,y) >= Cb(x,y)
0, otherwise

Rule4: R4(x,y) = 1 ,if(Cr(x,y) >= Cb(x,y)
0, otherwise

Step 4: Area detection

This method is used to detect dispersion of fire pixel area in the sequential frames. Area counts the number of pixels in an object [8]. In area detection method we consider two sequential frames which comes out from color detector then we check dispersion in minimum and maximum coordinate of X and Y axis.

We can have model of area detection as in Fig.5.

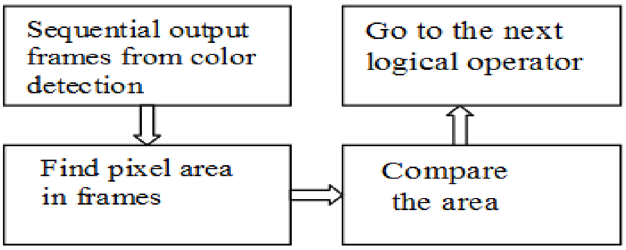

Fig.5 Model for area detection

Step 5: (Final Outcome)

We have taken two RGB image frames then algorithm is applied on it, and result is shown as in Fig.3 (a) and Fig 3(b). Sample RGB image frames having fire, it contains sub images of different steps in algorithm: 1^{st} image frame, 2^{nd} image frame having flame, red component of fire pixel according to condition as mentioned above, motion is detected between these two frames, and last sub image shows the fire pixel detected in image

V. Conclusion

We have proposed a fire-detection system for buildings which is based on image processing techniques. In the proposed system, computer vision technique is used which uses a new real time fire detection method. This system consists of three main stages: fire pixel detection using color, moving pixel detection and analysing colored fire moving pixels in consecutive frames to raise an alarm. Color segmentation is used to detect region of interest (ROI) of the fire. This technique uses HSV and YCbCr color models with given conditions to separate orange, yellow, and high brightness from the background. Frame difference technique is used to check fire growth. Our system will work very well after the occurrence of fire and will provide significantly faster detection based on light detection and analysis. This will result in significant reduction in loss of life and property. Overall accuracy of the proposed system will be better, demonstrating its effectiveness and usefulness.

VI. Future Scope

In future work, we will analyze the objects and shapes, such as shirts, bags, or other objects with orange color, which are approaching the camera. The relative proximity caused by change in size and intensity to the camera may cause false alarms. To improve systems fire detection performance Texture or shape information is used along with area information. Along with the fire detection technique the performance of fire pixel can be further improved by applying smoke detection in the early stage of fire. But, detecting smoke is a challenging task and is most likely to cause high false detections which may be caused from instances such as from fog, different lighting conditions caused by nature, and other external optical effects.

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