Fire and Smoke Detection System Using Image Processing

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Abstract: **This paper presents a system to detect fire and smoke with the use of computer vision-based techniques. Conventional fire and smoke detectors work on the principle of heat sensing. Our project aims to detect fire and smoke simultaneously with the help of video provided by the ordinary cameras. This method can be used to reduce the false alarm rate and to increase the spontaneity of the system. The key features of our system are as follows:**
1) Reducing false alarms caused by existing fire detection methods.
2) Monitor large open areas.
3) Simultaneous Fire and Smoke detection (by identifying gray cycle pixels) for accurate results.
4) Scalabiltiy option available.

IndexTerms **- Fire detection, Smoke detection, Image processing, Video based fire detection.**

I. Introduction

The number of accidents caused due to fire and harmful smoke is continuously showing an increasing trend. The amount of loss incurred due to such accidents is really huge. The developing infrastructure in the cities, harmful smoke from the factories and production industries, lack of efficient fire and smoke detection systems, lack of awareness among the people to react under such situations etc. are some of the major reasons for the human casualties and loss of wealth during such accidents[2].

Fire and smoke detection system sensors are used to detect occurrence of fire and smoke to make decision based on it. These detectors basically work on the principle of heat sensing and hence a considerably larger time to respond. These detectors need to placed at appropriate and fire prone areas. Since their area of coverage is less, they need to be carefully placed in various locations. Also, these sensors are not suitable for open spaces. Due to rapid developments in digital camera technology and video processing techniques, conventional fire detection methods are being to be replaced by computer vision based systems. Current vision based techniques mainly follow the color clues, motion in fire pixels and edge detection of flame. Fire detection and Smoke detection scheme can be made more robust by identifying the gray cycle pixels nearby to the flame and measuring flame area dispersion.

This project uses concepts of image processing to detect fire and smoke simultaneously. This project uses YCbCr color model to detect fire pixels. For the detection of smoke pixels the color characteristics such as saturation and the difference in the color pixel values are used. This project can also be used to detect real-time fire if provided with the video from the camera. The paper presents the algorithm for the detection of fire and smoke from the image and also the detection of fire from the video. This paper also presents a comparison between the images having fire and smoke pixels and the ones in which these are absent. The images having non-fire red and yellow pixels are not detected by the system and hence the false alarm rate is substantially reduced.

II. BASIC THEORY

The projects involves accepting a video input, video segmentation into frames and then detecting fire and smoke pixels in these frames. The color pixels in the image is converted into gray pixels and then the fire and smoke is detected. The color within the image can be represented by multiple color models such as RGB (Red, Green, Blue), YCbCr (Luminance, chrominance-blue, chrominance-red), and HSV (Hue, Saturation value). We use these color models to efficiently represent the primary colors or principles of brightness and chromatic aberration [3].

A. RGB Model

The RGB color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers. RGB is a device-dependent color model: different devices detect or reproduce a given RGB value differently, since the color elements and their response to the individual R, G, and B levels vary from manufacturer to manufacturer, or even in the same device over time. Thus an RGB value does not define the same color across devices without some kind of color management.

B. YCBCR MODEL

YCbCr, is a family of color spaces used as a part of the color image pipeline in video and digital photography systems. Y is the luminance component and Cb and Cr are the blue-difference and red-difference chrominance components. Chrominance Cb corresponds to the U color component, and chrominance Cr corresponds to the V component of a general YUV color space. YCbCr color space is defined in the ITU-R BT.601-5 and ITU-R BT.709-5 standards of ITU (International Telecommunication Union).The difference between YCbCr and RGB is that YCbCr represents color as brightness and two color difference signals, while RGB represents color as red, green and blue. The formulae for the conversion of RGB color model to YCbCr model are

$$Y = 0.299 \times R + 0.587 \times G + 0.114 \times B \quad (1)$$

$$Cb = 0.5 - 0.168736 \times R - 0.331264 \times G + 0.5 \times B \quad (2)$$

$$Cr = 0.5 + 0.5 \times R - 0.418688 \times G - 0.081312 \times B \quad (3)$$

C. HSV MODEL

The HSV model describes colors in terms of hue, saturation, and value (brightness).

Hue:- hue represents color. In this model, hue is an angle from 0 degrees to 360 degrees.

Saturation:- Saturation indicates the range of grey in the color space. It ranges from 0 to 100 percent.When the value is 0, the color is grey and when the value is 1, the color is a primary color. A faded color is due to a lower saturation level, which means the color contains more grey.

Value:- Value is the brightness of the color and varies with color saturation. It ranges from 0 to 100 percent. When the value is 0 the color space will be totally black. With the increase in the value, the color space brightness up and shows various colors.

The colors used in HSV can be clearly defined by human perception, which is not always the case with RGB. The formulae for the conversion of RGB color model to Hsv color model are,

$$V = \max(R, G, B) \quad (4)$$

$$S = 255 \times (V - \min(R, G, B)) / V \quad (5)$$

$$H = \begin{cases} 60 \times (G - B) / S & V = R \\ 180 + 60 \times (B - R) / S & V = G \\ 240 + 60 \times (B - R) / S & V = B \end{cases} \quad (6)$$

III. WORKING

The block diagram shown in Fig.1 represents the computer based fire detection unit and the working can be represented by the flowchart shown in Fig.2[1]. The fire detection unit comprises of the following components

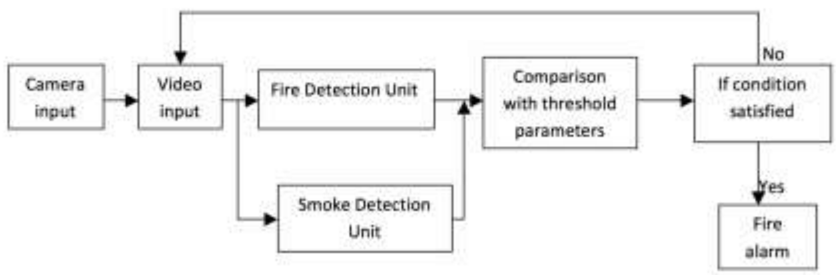

Fig 1. Block Diagram of Fire and Smoke Detection unit

A. VIDEO ACQUISITION

This unit provides the video input to the image processing block. The frames from the video are extracted and then sent to the image processing block. The video can be acquired by camera unit for real-time detection of fire [5].

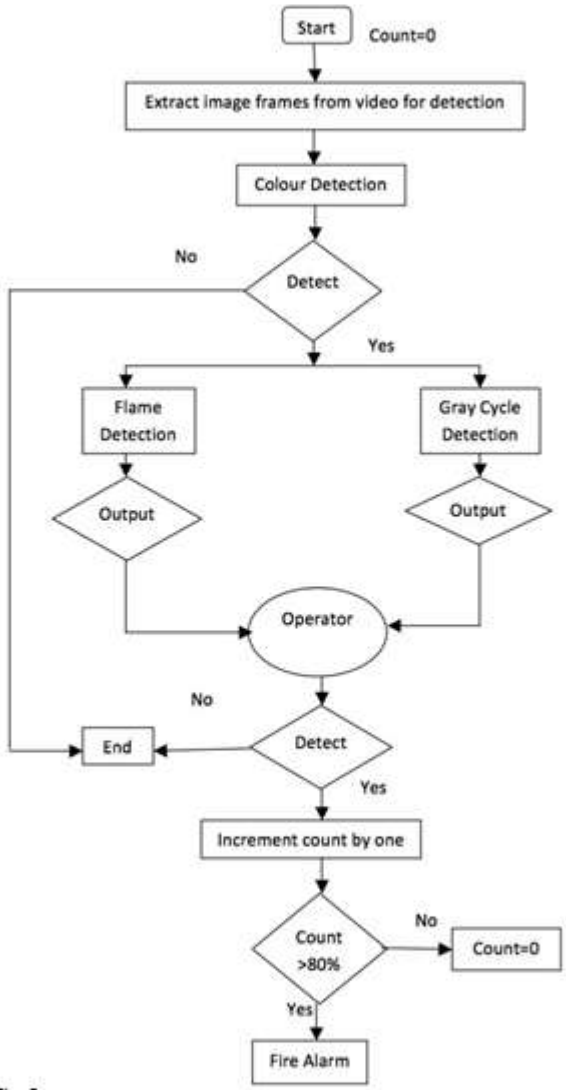

Fig 2. Flowchart

B. FLAME DETECTION UNIT

The extracted images from the video input are sent to the flame and smoke detection unit. Here the image is converted from RGB to YCbCr and HSV color spaces using the above formulae respectively. A set of rules are created to detect whether a pixel is a fire pixel or not. The RGB and the YCbCr function values are compared with a threshold value. If all the conditions are satisfied by a pixel then it is considered to be a fire pixel i.e if $f(Cb(x, y), Cr(x, y)) > T$ then the pixel is a flame pixel else it is not. The Fig.3 shows the flame detected output of the input image. Here the flame detection function is applied to the input image and the fire pixels are displayed. The observations show that the region in which fire is present is highlighted and the region in which fire pixels are absent is ignored. Thus even if non-fire pixels analogous to fire are present in the image they are ignored[3][4].

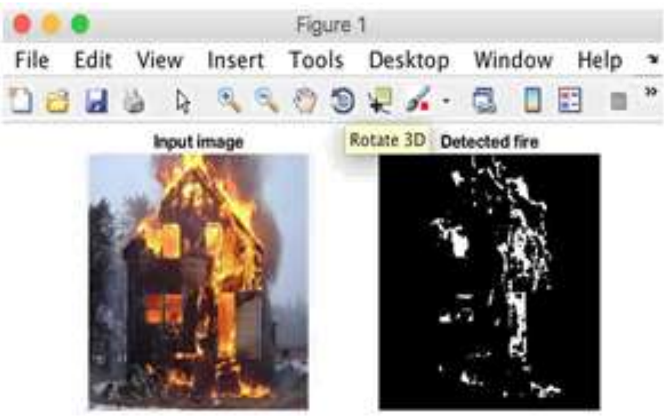

Fig 3. Fire detected output

C. SMOKE DETECTION UNIT

Detection of fire pixels is done by extracting the luminance and chrominance components and comparing then with a predefined threshold. On the contrary, the smoke pixels are devoid of chrominance components. There is a variation in the color of the smoke as its temperature changes. Initially when the temperature of the smoke is low the color of the smoke is in the range from white-bluish to white. As the temperature of the smoke increases, the density of the smoke increases and the color of the smoke gets in the range from black-grayish to black. Since the smoke pixels are usually grayish in color, they are formulated as follows,

$$|R(x, y) - G(x, y)| \leq T h \quad (7)$$

$$|G(x, y) - B(x, y)| \leq T h \quad (8)$$

$$|R(x, y) - B(x, y)| \leq T h \quad (9)$$

Here Th is the global threshold ranging from 15 to 25. The above equations state that the intensities of the smoke pixels in the RGB color model should be similar. Smoke is an early sign of fire and hence it needs to be detected at an early stage,i.e., at low temperature. Hence the color of the smoke is supposed to be white-bluish and so the saturation of the color is extremely less. The saturation parameter is therefore given by,

$$S(x, y) \leq 0.1 \quad (10)$$

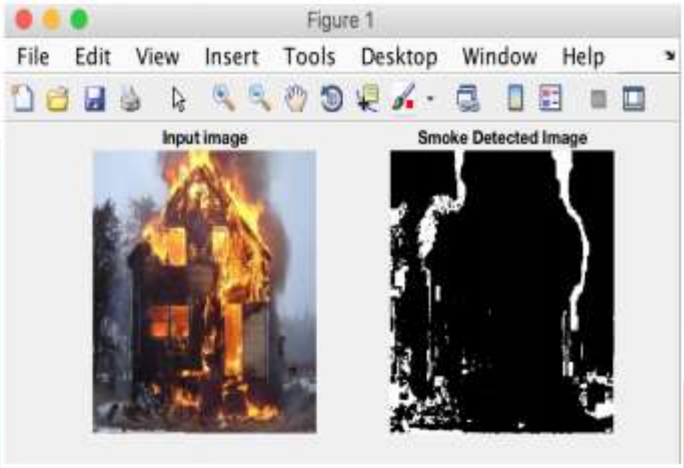

Fig 4. Smoke detected output

The Fig.4 shows the smoke detected output of the input fire image. Here the smoke region can be obtained by using the above formulae and comparison with the threshold conditions[4].

IV. RESULT ANALYSIS

Here the video input is given to the image processing based flame detection system. The video is separated into individual frames which are then sent to the fire detection unit and the corresponding fire is detected as shown in the Fig.5. Thus real time flame detection is thus obtained which can be used to trigger different alarm.

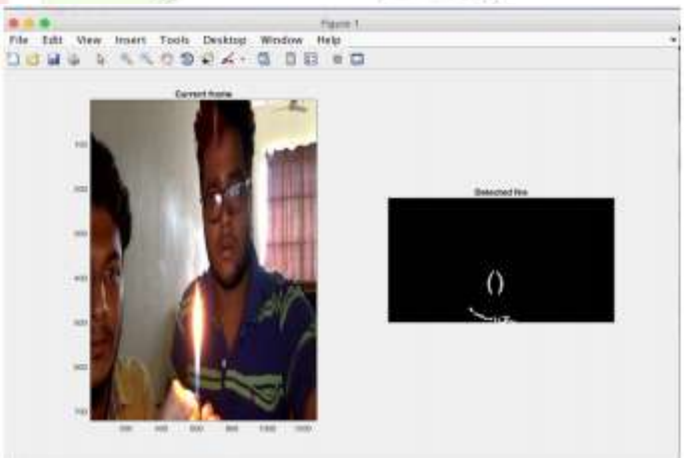

Fig 5.Flame detected output from video frame

V. CONCLUSION

To reduce the false alarm caused by smoke detectors and to effectively detect fire in closed and open areas, the method proposed in this paper can be used. It can be used along with the traditional smoke detectors or as independent systems. It can also be incorporated in the existing surveillance camera systems and hence becomes economical too. Through image processing, flame and smoke pixels were detected which can be verified by humans through their own vision too.

VI. FUTURE SCOPE

The detection of smoke involved a lot of noise when the smoke was transparent and tended to blend with the picture. This problem can be solved by artificial intelligence algorithm based on the neural network which makes the machine self learning, thus reducing the misjudgment rate and enhancing the system efficiency, stability, etc.The machine learning will enable the system to adapt to the variations in smoke characteristics by computing and comparing it with the previous occurrences of fire in that area.

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