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# Forest Fire Detection in Forest Video using Image Processing

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**Abstract:** Forest is one of the most important and essential natural resources. The forest fire is most common hazard results a very serious economic and wild life loss. The forest fire detection is an important issue in recent year. This study presents a forest fire detection system using image processing technique. The motive of proposed research is to create simple, effective, fast and accurate forest fire detection system. A proposed method detects flame, smoke and their motion in a video of the forest area captured by a fixed low-cost camera. Using one color space to detect the flame and smoke creates confusion in classification. To avoid confusion in classification this system uses RGB, HSV and $YC_bC_r$ color space, each has its own advantage to detect fire components. Firstly, video frame will analyze the RGB, HSV and $YC_bC_r$ color components and find the desired existed flame as well as smoke color. Then, it will find the region in the video frame which has a movement towards smoke and flame. After comparing the results with old methods, proposed system shows more accurate fire detection rate and lesser false detection rate.

**Key words:** Background subtraction, $YC_bC_r$ Model, RGB Model, HSV Model, fire detection, flame detection, motion detection, smoke detection

## INTRODUCTION

Forest is a complete ecosystem having many plants and animals. From many year one of the most hazardous problems faced all over the world is the forest fire. It causes terrible damage which leads to severe economic loss.

In recent year various fire detection systems were proposed most of them use sensors. Sensors are very tiny and their life depends only on battery power. To cover an area of forest huge number of sensors is required. After deploying sensors in the large open space like a forest, replacement or recharging of the battery is not possible every time. Also, the sensors can recognize a fire if it is near to the fire which causes damage to the sensor.

Due to the fast growth of digital technology and video processing, traditional fire detection systems are replaced by Computer Vision Based Systems (CVBS). CVBS uses three stages, first is a classification of the flame pixel, second is moving object segmentation and last is candidate region analysis. The fire detection system performances rely on research of fire pixel classifier that creates large areas on which remaining system operates. Therefore, an accurate precise fire pixel classifier is required with higher true detection rate and lesser false detection rate. There are some methods which precisely research on fire pixel classification. The categorization of fire pixel can be deliberate in both the gray scale and color video sequences.

In recent year video surveillance become very popular tool for supervising. It is widely and effectively used in various fields such as security and protection of the environment, law enforcement, etc. The most effective idea for detection of forest fire using image processing is to use the color indices to differentiate cultivated areas from other areas (Cruz *et al*., 2016; Cai *et al*., 2016; Zaidi *et al*., 2015).

The proposed method is based on color indices, a good color model choice for detection of fire and moving pixel is an important task. In CVBS, fire and moving pixel detection plays a crucial role. Detection of flame in the forest video is not enough because sometimes flame may be hidden and it will detect when it increases rapidly. Therefore, only flame detection is not enough to detect fire in an earlier stage in the forest area. Hence, the proposed system considers the flame as well as smoke. Fire releases smoke and it rises fast from bottom to top which can help to detest forest fire at earlier.

Effective forest fire system should necessary to detect smoke as well as flame but with one color space it will difficult to set threshold for both fire components. Thus, different color spaces and motion clues will use to

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detect the fire components. This method takes the advantage of motion of both the fire and smoke. Motion will help to develop a forest fire system more effective. The proposed method uses: fixed low-cost camera equipment. Specially designed fast and effective detection algorithms for forest fire detection based on color and moving pixel which uses more than one color spaces.

In this method RGB, HSV and $YC_bC_r$ color space is used to meet the aim of finding a fire in forest area. RGB not detects the flame and smoke accurately by itself that creates confusions in classification. RGB color space can use with HSV and $YC_bC_r$ color space gives most accurate detection rate. RGB and $YC_bC_r$ color space is more suitable for daylight which is used for flame detection and HSV color space is used for smoke detection. Firstly, the color components of the frame are extracted by using RGB, HSV and $YC_bC_r$ color space. After extraction components are analysed to decide whether there exists any flame and smoke and then will research on motion of flame and smoke.

**Literature review:** Corresponding to the forecast, forest fire, containing fires in tropical rain forests will cut half of the global forest stand by the year 2030 (Cai *et al*., 2016). Over 100.000 $km^2$ forest area is burnt in Russia and USA. In Europe, every year over 10.000 $km^2$ area of forest is burnt. Forest fires shares total 20% of complete world $CO_2$ diffusion. The rate of forest fire is also, increased due to global warning. Therefore, various fire detection systems were proposed. In this study brief discussion about various fire detection techniques is given.

A vision-based fire detection monitoring system is developed to monitor any area or spaces, especially the forest area and for a places where our vision is limited. By using a surveillance system, man power required to guard the area can be reduced. This system was easy to install and cheap. Due to brightest image pixels fire is more accurately detected at night. But in a day light condition it is difficult to identify fire due to brightness (Zaidi *et al*., 2015). This is the limitation of vision-based system.

Smoke and fire detection method based on $YC_bC_r$ color space which can quickly identify fire in picture of the area taken by the camera. The method first detects smoke before detecting flame. When area will detect with smoke, it shows a message on the security node. When a flame started to break with the area under consideration, the corresponding flame region will segments. The area of the flame rises of the successive frames then an alarm will sound (Gharge *et al*., 2014). In this method, smoke is detected first before the flame an alarm will sound as flame increases in size otherwise not, we need a system which detects fire from earlier stages doesn't wait to increase flame.

Different sensor based methods for fire detection was proposed in the literature which creates alerts when a fire occurs. Radio acoustic sensors, ionization smoke sensors, projected (optical) to beam smoke sensors, etc. has various signals to detect the fire based on combustion process. But sensors are costly and has limited battery power, so, these kind of systems was expensive than traditional systems (Millan-Garcia *et al*., 2012; Sahin and Ince, 2009; Yuan *et al*., 2015).

By Tang and Shao (2015) and Salami *et al*. (2014), fixed surveillance system was introduced. This system faces problems with fixed cameras on tower. To provide high quality vision videos this system requires expensive cameras. It is not possible to cover vast area of forest by using high cost cameras. Thus, this method has limited capacity and was unable to monitor huge area of the forest. This limitation can be solved by using satellites and areal transportation system for monitoring. But the cost of this system is more than the previous one. Also, due to unpredictable climate conditions, this method was unable to provide accurate results.

The Unmanned Aerial Systems (UASs) is introduced by Watts *et al*. (2012). It is the system without human pilot and also, known as drones. It is good alternative for critical forest areas. Many research groups use this system in fire detection.

## MATERIALS AND METHODS

**Proposed forest fire detection approach:** This study provides the flow chart and techniques for the proposed method (Fig. 1).

**RGB color model:** The RGB color space is used to analyze red color information, it is use to detect flames on frame of video. RGB color model extracts certain color tones while attenuating other unwanted ones. There are three different elements of color pixel. R, G and B. The color pixel can extract into these three individual elements R, G and B which is used for red color detection. This module firstly extracts individual colored elements from frame, normalized each element and module receives color value for each R, G and B element. Then eliminate G and B values which are not used for flame detection. After that, the system subtracts the undesirable color value from needed color value, i.e., subtraction of G (Green) and B (Blue) color value from R (Red) color value and get red color value existed on frame. Similarly, green color value

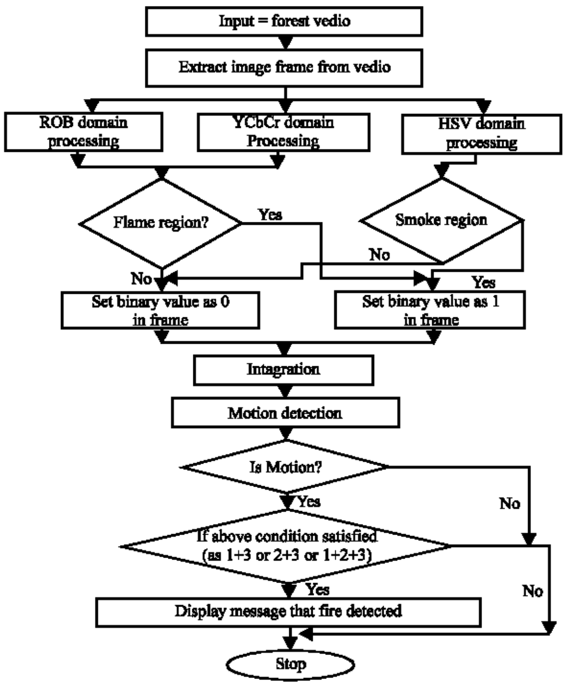


Fig. 1: Flow chart of proposed algorithm

is obtained and threshold is compared with condition's value. The system uses subtraction of green value from red values to eliminate the background green color of the forest. Lastly, threshold value is compared with condition's values of the frame. If condition's value is more than or same to the threshold value, then the frame is labelled with "1" (white) otherwise with "0" (black). The threshold is set by referring table of color range.

**Step in RGB domain processing:**

- Video acquisition
- Extract image frames from video
- Getting R, B, G color components
- Normalization of color components:

$$R = \frac{R}{R+G+B}, G = \frac{G}{R+G+B}, B = \frac{B}{R+G+B}$$

- Calculation of colours needed to flame detection:

$$Red\,1 = R\text{-}G \quad (1)$$

$$Red\,2 = R\text{-}B \quad (2)$$

Then:

$$Red = Red\,1+Red\,2$$

From Eq. 1 and 2:

$$Red = R\text{-}G+R\text{-}B$$

And final:

$$Red = 2\,R\text{-}G\text{-}B \quad (3)$$

- Background subtraction

Enhance certain color tones while attenuating other unwanted ones, here, flame detected as:

$$A1 = R\text{-}G+R\text{-}B \quad (4)$$

Now, we are detecting flame in forest area which is green:

$$A2 = G\text{-}R+G\text{-}B \quad (5)$$

So, enhance flame color tone while attenuating green which unwanted as:

$$A = A1\text{-}A2$$

From Eq. 4 and 5.

- Binarization through application of TFFD:

$$T_{FFD} = \frac{\delta A1+\delta A2}{2}$$

- Labeling of segmented regions:

$$G(x, y) = \begin{cases} 1 \text{ if } A \geq T_{FFD} \\ 0 \text{ if } A < T_{FFD} \end{cases}$$

**$YC_bC_r$ color model:** The $YC_bC_r$ color model is also, used for flame detection. Using the RGB color model, the system gets the red color which is needed for flame detection. But brightness occurs due to flame rise detected by $YC_bC_r$ color module. $YC_bC_r$ color space is more effectively separates luminance from chrominance as compare to RGB color. The proposed system worked similar to the RGB model that extracts certain color tones while attenuating other undesirable ones. In $YC_bC_r$ color space, there are 3 elements module as, Y, $C_b$ and $C_r$. This module extracts all elements from frame, normalized each element and gets the color value for each Y, $C_b$ and $C_r$ elements of frame. Then cuts unwanted color value from wanted color value by doing subtraction. There are two conditions, condition 1 is subtraction of $C_b$ color value from Y color value and condition 2 is subtraction of $C_b$ color value from $C_r$ color value, then apply a threshold values to both conditions. The system uses separate threshold values for each condition if values in both conditions are greater than the threshold a value then the frame is labelled with "1" (white) otherwise with "0" (black). The threshold is set by referring (Table 1). In Table 2, we are showing color values that we need for flame detection, also showing all color values present in the flame.

Table 1: Range in RGB color space

| Color range/Component values | R | G | B |
|---|---|---|---|
| Red | 255 | 0 | 0 |
| Light pink | 255 | 204 | 204 |
| Yellow | 244 | 203 | 71 |
| Bright yellow | 244 | 221 | 157 |
| Orange | 252 | 170 | 46 |
| Orange brown | 205 | 93 | 47 |
| Red brown | 189 | 34 | 21 |
| Brown | 114 | 67 | 51 |
| Dark gray | 134 | 115 | 92 |
| Brown gray | 154 | 137 | 111 |
| Gray | 186 | 178 | 159 |
| Bright gray | 232 | 211 | 204 |
| Blue gray | 199 | 207 | 245 |

**Step in $YC_bC_r$ domain processing:**

- Video acquisition
- Extract image frames from video
- Getting Y, Cb, Cr color components
- Normalization of color components:

$$Y = \frac{Y}{Y+Cb+Cr}, CB = \frac{Cb}{Y+Cb+Cr}, CR = \frac{Cr}{Y+Cb+Cr}$$

- Two conditions needed to flame detection:

Condition: Y-CB
Condition: CR-CB

- Labeling of segmented regions:

$$G(x, y) = \begin{cases} 1 \text{ if condition } 1 \geq T_{FFD} \\ 0 \text{ if condiyion } 2 \geq T_{FFD} \end{cases}$$

**HSV color model:** The system uses the HSV color space, only because the HSV color space has saturation and the intensity properties. The HSV color component consists of three main integral parts as Hue, saturation and value. If the saturation value removes from HSV components that means no color is a shade of gray between black and white. Brightness in the picture is actually a light concentration or the amount of light ranges from black up to white. The proposed system worked similar to the RGB Model that extracts certain color tones while fading other unwanted ones. This module extracts all elements from the frame as H, V and S, similar to previous two modules. Normalized each element, the module gets the color value for each element and then eliminate the undesirable color value from needed color value. There are two conditions to extract smoke color value from the frame. Condition 1 subtracts saturation from hue and condition 2 subtracts saturation from value. Then apply a threshold value to

Table 2: Value for red color in $YC_bCR$ color space

| Color components/values | Range |
|---|---|
| R | 255 |
| G | 0 |
| B | 0 |
| Y | 82 |
| Cb | 90 |
| Cr | 244 |

both conditions. The system uses separate threshold values for each condition if values in both conditions are greater than the threshold a value then the frame is labelled with “1” (white) otherwise with “0” (black). The threshold is set by referring (Table 2).

**Step in HSV domain processing:**

- Video acquisition
- Extract image frames from video
- Getting H, S and V color components
- Normalization of color components:

$$H = \frac{H}{H+S+V}, S = \frac{S}{H+S+V}, V = \frac{V}{H+S+V}$$

- Two conditions needed to flame detection:

Condition 1: H-S
Condition 2: V-S

- Labeling of segmented regions:

$$G(x, y) = \begin{cases} 1 \text{ if condition} \geq T_{FFD} \\ 0 \text{ if condition } 2 \geq T_{FFD} \end{cases}$$

**Integration:** After getting labeled frame from each model, the system integrates all labeled frames into one. Integrated labeled frames are used for further process because frame in RGB module is labeled if red part is in frame otherwise not which is not enough to forest fire detection system. Similarly, labeled frame $YC_bC_r$ module gives information of bridger part, smoke part information on labeled frame from HSV module. The system detects all components of fire by integrating all labeled frames from RGB, $Yc_bC_r$ and HSV modules into one frame. This integrated frame gives information about flame and smoke. The final integrated labeled frame is given for motion detection to get more effective results.

**Motion detection:** In many computer-vision applications reorganization of moving object from a video sequence is an essential and difficult task. Background subtraction is a regular method used to detect moving object from video frame that some what vary from a background model. For detection of motion in a continual video rill, three different methods are used in the background subtraction. For comparing the current frame with the last one is the most common method. In this study, frame background algorithm is used to recognize the moving pixels in the video. The motion will detect by comparing the current frame with the previous frame. After completing the process of all modules, the system lastly checks whether the smoke or flame is detected in motion or not. If yes then proposed system sets the message as fire is detected.

**Color range:** The color range used by proposed system is given in Table 1-3 that helps in setting a threshold in RGB, HSV and $YC_bC_r$ modules (Watts *et al*., 2012).

Table 3: Value for smoke in HSV color space

| Color components/values | Range |
|---|---|
| H | 240 |
| S | 0.05 |
| V | 0.757 |

## RESULTS AND DISCUSSION

**Detection of flame and smoke by each module and integration:** Following outputs shows the results of each module that we have used in our system, they are showing the results from RGB, $YC_bC_r$ and HSV module and result of integration of all module. Results show that the RGB and $YC_bC_r$ module detect flame properly where HSV module detect smoke properly in each condition. Output frame from each module is labelled with white and black color, detected part shown in white color and others part is in black color. Each modules shows output frame that contains detected part in white color if any, else frame contain black color. Detected flame and smoke shown in white color as follow. Integration of frames from all modules shows smoke as well as flame area accurately as present in input frame.

Figure 2 shows that the current frame of selected video is shown in Fig. 2a that current frame is given to all modules to process. Figure 2b shows red color detected by RGB domain as per input frame if input frame contain red color of flame than RGB domains shown that area, brightness detected in flame by $YC_bC_r$ domain is shown in third row (Fig. 2c), smoke detected by HSV domain is shown in fourth row (Fig. 2d) and integration of all module is shown in fifth row (Fig. 2e).

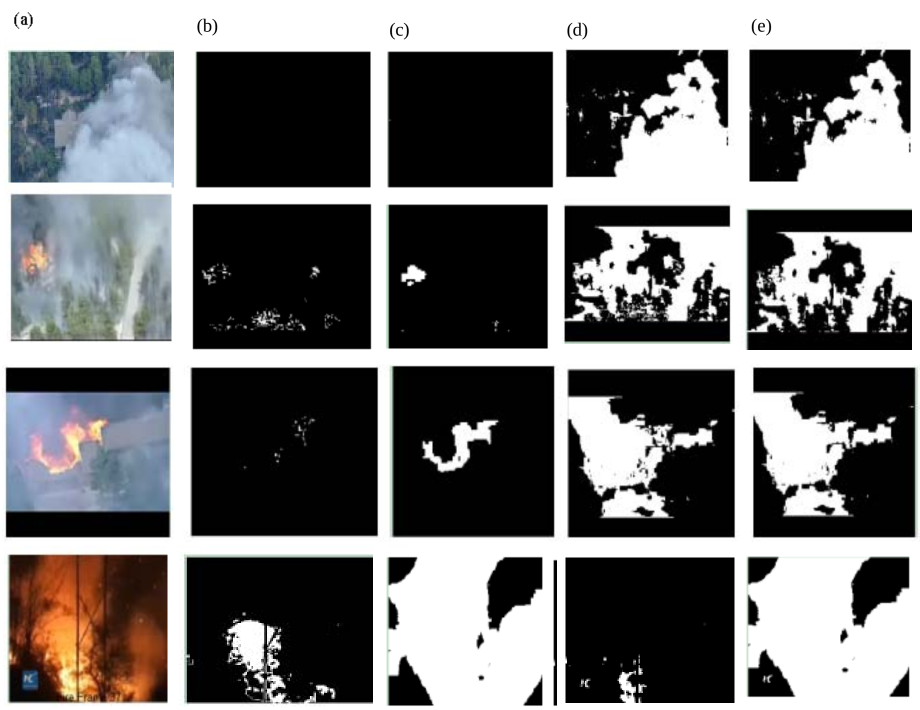


Fig. 2: Experimental rsults: a) The original image; b) Study with flame detected by RGB domain; c) Study with flame detected by $YC_bC_r$ domain; d) Study with smoke detected by HSV domain and e) Study with fire and smoke which is integration of b-d

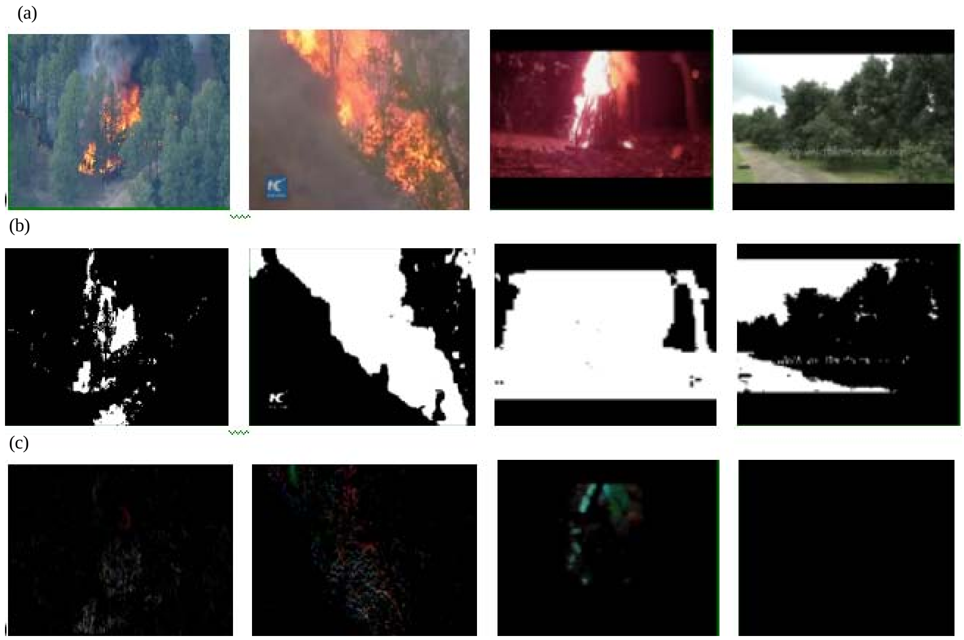


Fig. 3: Experimental Results: a) The original image; b) Integration of RGB, $YC_bC_r$ and HSV module and c) Study with motion of flame and smoke

**Detection of fire and motion:** Figure 3 shows the current frame of selected video in first column, integration of results from all modules is shown in second column and motion in fire pixels is shown in third column. Considering both integrated video frame and motion frame output is given in window whether fire is detected or not.

Figure 3 flame and smoke is in input video flame in first three rows as per this input frame. First three images in Fig. 3b and c show the output that shows the detected fire in Fig. 3b and fire motion in Fig. 3c. Last image that is forth image in Fig. 3a is an input image with no fire as per this input image, last image in Fig. 3b and c shows the output. Our final output is shown in column (Fig. 3c) which shows the motion of fire area that detected in Fig. b. We consider following cases for the testing the system.

**Case-1:** We are considering the forest video for the testing purpose. In our first case we consider forest video. In selected video there are total twelve video of fire which contains flame. System processes that video and detects flame in 11 video and classifies fire area from rest of area. Our system display message as fire detected if it detects flame.

**Case-2:** We are considering the forest video for the testing purpose. In our second case we consider forest video. In selected video there are total twenty video of fire which contains smoke. System processes that video and detects smoke 20 video and classifies selected fire area. Our system display message as fire detected if it detects flame.

**Case-3:** In our third case we consider forest video which contains no fire. System processes that video and detects as no fire successfully. Our system display message as no fire detected if forest video do not contain fire.

In the table proposed system is compared with the existing system developed by Cruz. So, table shows the accuracy of both the systems. So, the overall accuracy of system is 95.67%.

## CONCLUSION

In this study an RGB, HSV and $YC_bC_r$ color based forest fire detection system is proposed. The system uses forest video as input and finds smoke as well as a flame by analyzing color components with the help of motion of the flame and smoke. It will give the result in binary video frame if the fire is detected. The proposed fire detection system is compared with the system defined by Cruz *et al.* (2016) and by using more than thousands of images comparative analysis is carried out. The result shows that proposed system provides excellent performance in terms of higher fire detection rate and less false detection rate. Due to consideration of motion, the performance of the proposed system is improved. This system is very prominent about the result as it is more effective and faster than previously developed ideas. Proposed idea can be used in real time.

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