Image Processing Based Forest Fire Detection using YCbCr Colour Model

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Abstract- **In this paper image processing based forest fire detection using YCbCr colour model is proposed. The proposed method adopts rule based colour model due to its less complexity and effectiveness. YCbCr colour space effectively separates luminance from chrominance compared to other colour spaces like RGB and rgb(normalized RGB). The proposed method not only separates fire flame pixels but also separates high temperature fire centre pixels by taking in to account of statistical parameters of fire image in YCbCr colour space like mean and standard deviation. In this method four rules are formed to separate the true fire region. Two rules are used for segmenting the fire region and other two rules are used for segmenting the high temperature fire centre region. The results obtained are compared with the other methods in the literature and shows higher true fire detection rate and less false detection rate. The proposed method can be used for real time forest fire detection with moving camera.**

***Keywords-*: Fire detection, YCbCr colour model, Image processing, mean, standard deviation.**

I. INTRODUCTION

The most common hazard in forest is the forest fire. Forest fire causes great harm to the forest and results a very serious economic losses. Nowadays almost all the fire detection system uses sensors. The accuracy, reliability and positional distributions of the sensor determine the betterment of the system. For high precision fire detection systems, large numbers of sensors are needed in the case of outdoor applications. Sensors also need a frequent battery charge which is impossible in a large open space. Sensors detect fire if and only if it is close to fire. This will lead to damaging of sensor.

Computer vision based systems replaces conventional fire detection systems, due to the rapid development of digital camera technology and video processing. Computer vision based systems use three stages [1-4]. 1. Flame pixel classification. 2. Segmentation of moving object. 3. Analysis of the candidate region. The performance of the fire detection system depends on the performance of the fire pixel classifier which generates major areas on which rest of the system operates. Thus a precise fire pixel classifier is needed with high true detection rate and less false detection rate. However there exist some algorithms which directly deals with fire pixel classification. The fire pixel classification can be considered in both in gray scale and colour video sequences.

Low cast CCD cameras are used to detect fires in the long range passenger aircraft [5]. This method employs statistical features mean, standard deviation and second order moments along with the non image features such as humidity and temperature. The system can also be used in smoke

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detector to reduce the false alarm. The system also provides visual inspection capability to confirm the presence or the absence of fire for the aircraft crew.

T.Chen et al. [1], developed a set of rules to separate the fire pixels using R, G and B information. B.U. Totryin et al. [2] used a mixture of Gaussians in RGB colour space which is developed from a training set of fire pixels, instead of using a rule based colour model in [1]. B.U. Totryin et al.[3] employed a hidden markov models to detect the motion characteristics of the fire flame that is fire flickering along with the fire pixel classification. G. Marbacr et al.[6] used YUV colour space for the representation of video data, where the candidate fire pixels are obtained by the derivative of the luminance component Y and the candidate fire pixels are confirmed by using the information from the chrominance components U and V. But in this method the number of test conducted was not mentioned. Wen- Homg et al. [7], used HSI colour model to separate the fire pixels. They have developed the rules for brighter and darker environments. After segmenting the fire region based on HSI rules the lower intensity and lower saturation pixels are removed to avoid fire aliases (fire like region). They also formed a metric based on binary counter difference images to measure the burning degree of fire flames such as no fire, small, medium, and big fires. Their result includes false positives and false negatives. But there is no way to reduce the false positives and false negatives by changing their threshold value. T. Celik et al. [4] formed number of rules using normalized (rgb) values in order to avoid the effects of changing illumination. In this method statistical analysis is carried out in rg, rb and gb planes. In each plane three lines are used to specify a triangular region representing the region of interest for fire pixels. A pixel is declared as fire pixel if it falls in to the triangular region of rg, rb and gb planes. Even though the normalized RGB colour space overcomes the effects of variation in illumination to some extent further improvement can be achieved by using YCbCr colour space which separates luminance from chrominance. Turgay Celik et al. [8] proposed a generic colour model to segment the flame pixel from the background using YCbCr colour model. This method segments the flame region except the flame centre. But this method classifies fire pixels only based on colour information. Vipin V[9] proposed a model to segment the fire from the image which uses RGB and YCbCr colour space. This method does not work well under all environmental conditions and is not reliable.

This paper proposes YCbCr colour model for flame pixel classification using statistical feature of the fire image i.e, mean and standard deviation because in YCbCr colour space, the relation between pixel is more compared to other colour models. The centre of the flame is white in colour like cloud. We developed a new rule to segment the fire centre from the background in YCbCr colour space. The proposed method was tested for nearly 800 images collected from the internet with different illuminations. Compared to the previously introduced flame pixel classification methods, the proposed method detects fire with high true detection rate and low false detection rate. The proposed method gives 99.2% true detection rate. The proposed method provides significant improvement over other methods used in the literature.

II. PROPOSED FOREST FIRE DETECEION METHOD

This section deals with the proposed fire pixel classification method. The flow chart for the proposed method is given below. It uses YCbCr colour space. Because YCbCr colour space separates luminance information from chrominance information than other colour spaces. For fire pixel classification, four rules (Rule I, Rule II, Rule III, and Rule IV) are formed. The colour of the fire at the high temperature centre region is white. However the colour of the fire in the region except the centre region is of the colour that varies from red to Yellow. Among the four rules used in the proposed method, Rule I and Rule II are used for the segmentation of fire flame region. Rule III and Rule IV are used for the segmentation of centre fire pixels (high temperature region). Finally the image obtained by satisfying Rule I & 2 and the image obtained by satisfying Rule III & IV are added to get the true fire image.

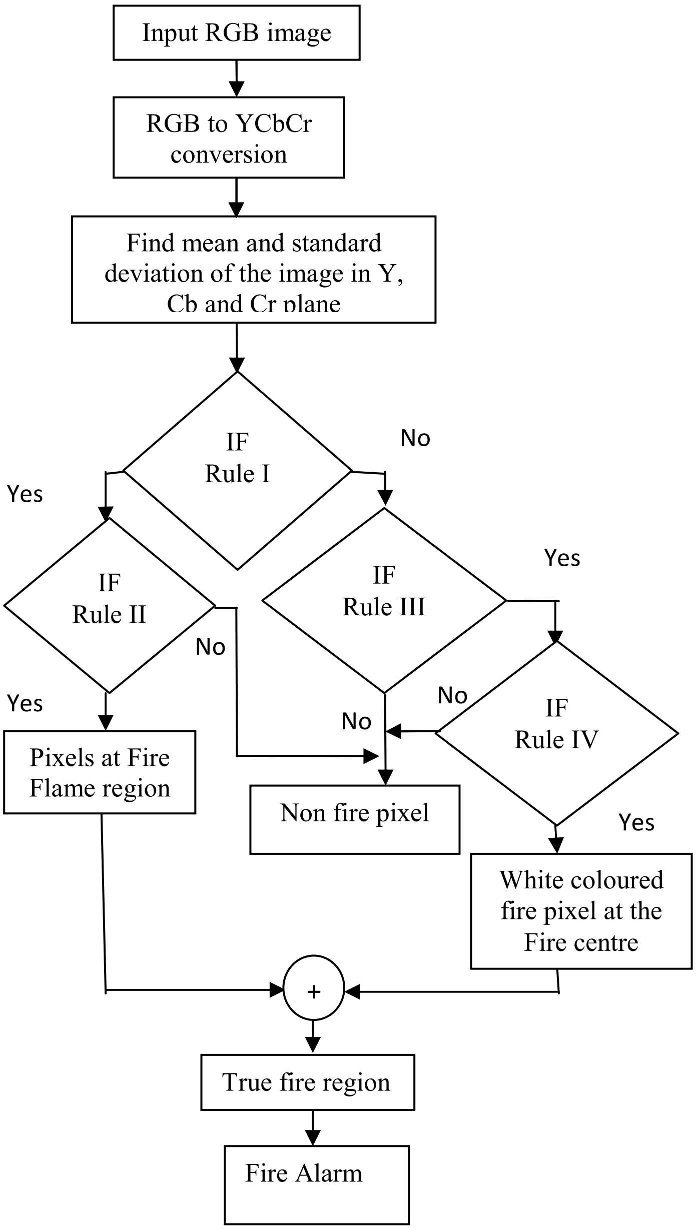

Fig 1. Flowchart of proposed fire detection system

III. SEGMENTATION OF TRUE FIRE REGION

It comprises of the classification of low temperature fire flame pixels whose colour varies from red to yellow (not the high temperature fire centre). Each digital colour image has three colour planes: Red (R), Green (G) and Blue (B). Each colour plane is quantized in to discrete levels, generally 256 (8 bits per colour plane) quantization levels are used for each plane. White colour is represented by (R,G,B)= (255, 255, 255). Black is represented by (R,G,B)= (0,0,0). A colour image consists of h pixel is represented by spatial location in the rectangular grid. (R (x,y), G (x,y), B (x,y)) is the colour vector corresponding to the spatial location (x,y).

In the fire region of the digital fire image, the value of red channel(R) is greater than the value of green channel (G) [1, 4]. In order to explain this concept clearly, we picked some sample images as shown in the fig. 2 (a). And we have separated the R component, G component and B component. From figure 1 (b-d), it can be noticed that, in the fire region the intensity of fig. 2 b (R component) is greater than fig. 2 (c) (G component). In order to explain this idea better two samples are picked from fig. 2 (a) and segmented its fire pixels as shown in fig 3. Then the mean values are calculated for the segmented fire region of the original images. The results are shown in the Table 1. From the table it is clear that, on the average the fire pixels show the characteristics that their R intensity value is greater than G and G intensity value is greater than B. Many rules were formed in RGB colour space [1] to classify the fire pixel. When the illumination of the

Table 1. Mean values of R, G and B components of the manually segmented fire regions of fig 3.

Row index	R_{mean}	G_{mean}	B_{mean}
1	251	237	154
2	243	212	139

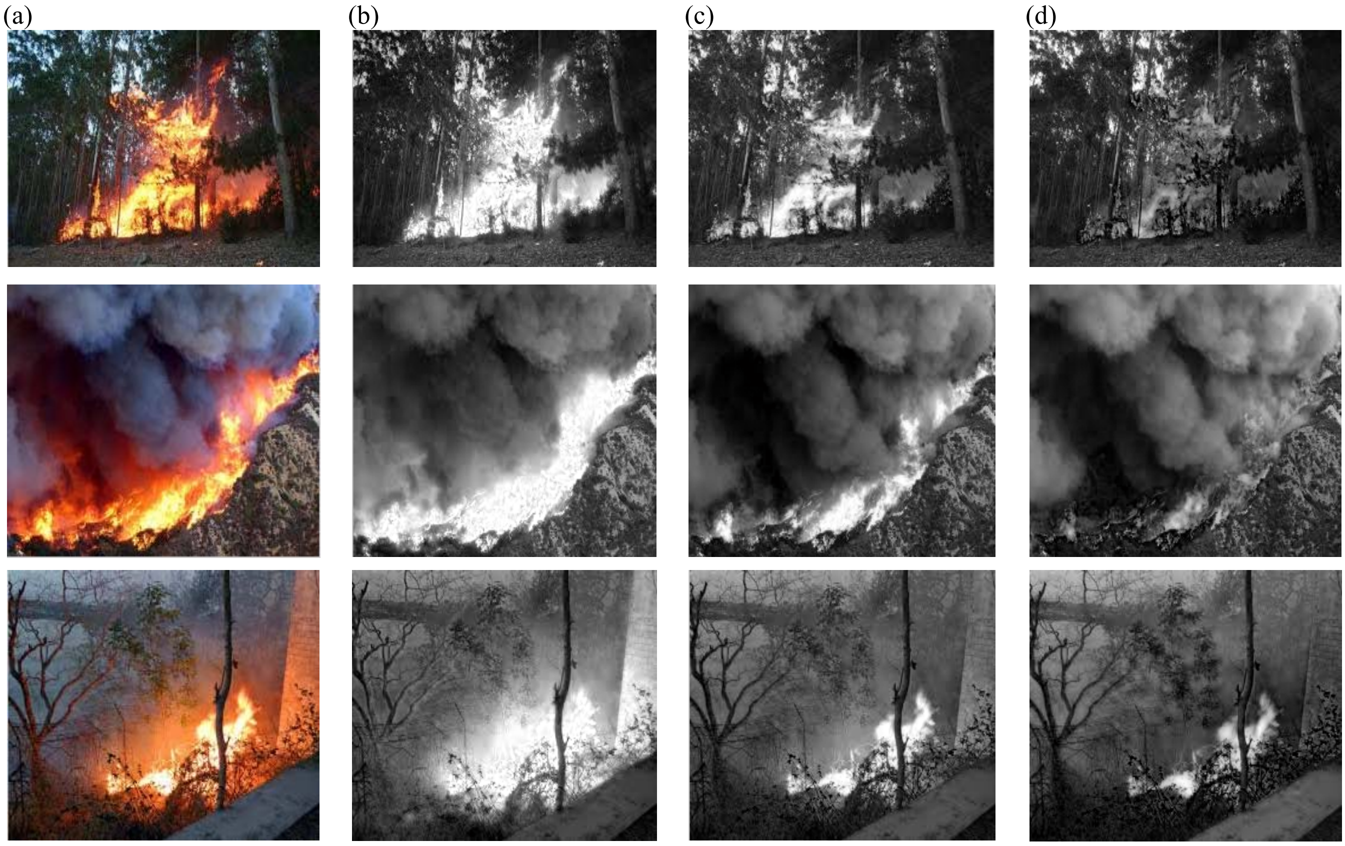

Fig. 2. Original RGB images in column (a), Red (R), Green (G) and Blue (B) components in column (b) - (d) respectively.

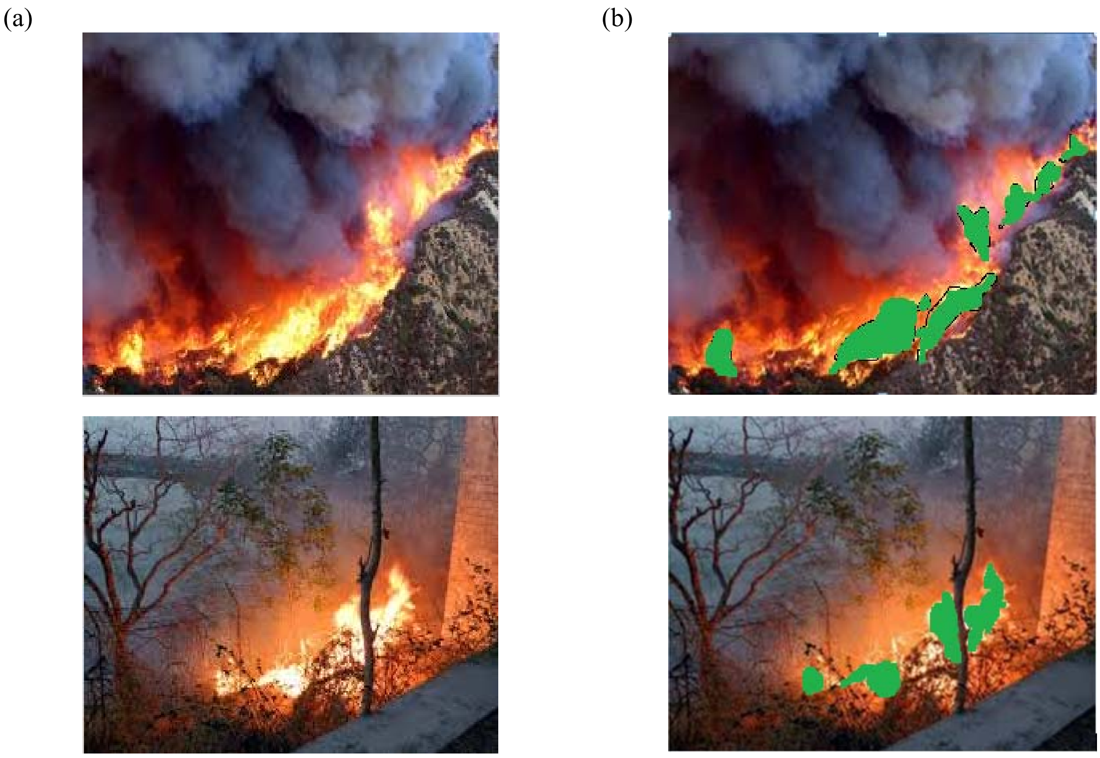

Fig. 3. (a) Input RGB image (b) Manually segmented fire region shown with green colour.

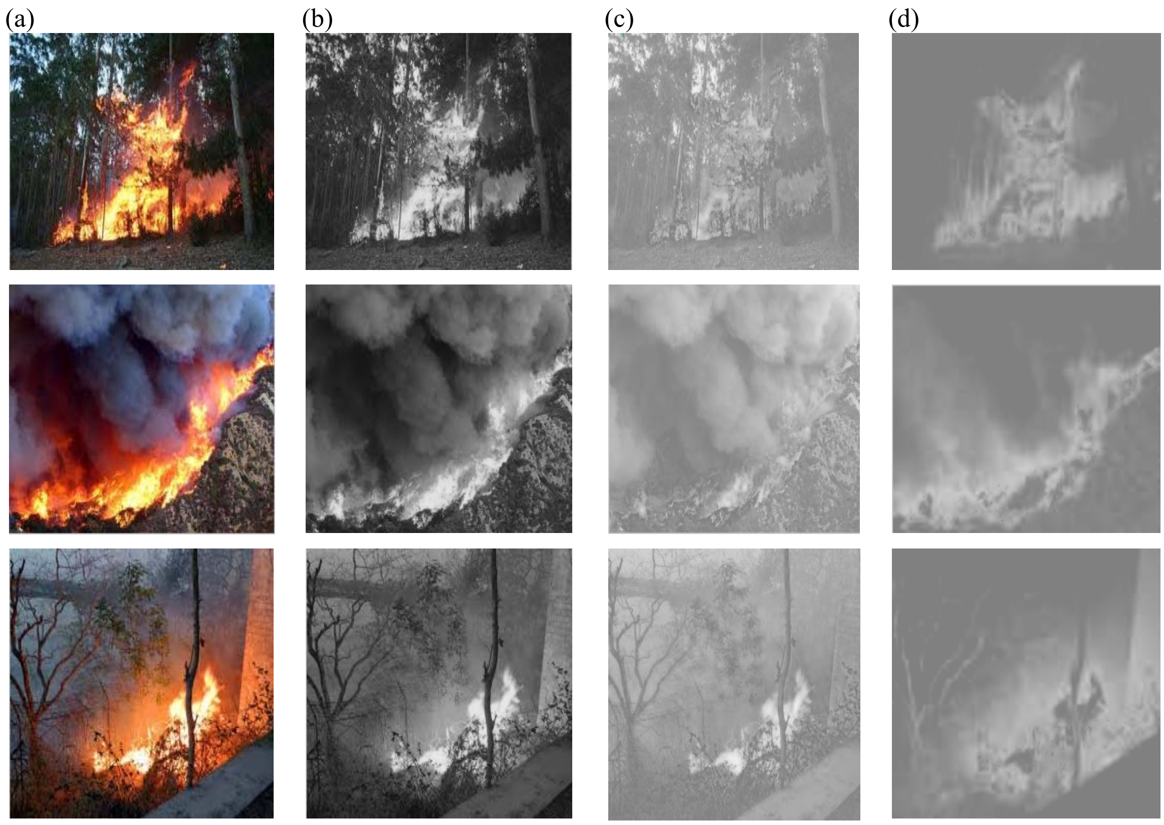

Fig. 4 (a) Input RGB image (b) Y component (c) Cb component (d) Cr component

input image changes it cannot perform well. Also in RGB colour space it is not possible to separate a pixel's value in to intensity and chrominance. The chrominance can be used in modeling colour of the fire rather than modeling its intensity. This gives a very strong representation for fire pixels. So there is a need for transforming RGB colour space into one of the colour space where the separation between intensity and chrominance is more discriminate. Based on the above concept we choose YCbCr colour space for the classification of fire pixels. Also conversion from RGB to YCbCr colour space is linear. The conversion from RGB to YCbCr colour space is shown below.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2568 & 0.5041 & 0.0979 \\ -0.1482 & -0.2910 & 0.4392 \\ 0.4392 & -0.3678 & -0.0714 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \quad \ldots(1)$$

here 'Y' is Luminance component, 'Cb' is the Chrominance Blue component and 'Cr' is the chrominance Red component. The range of 'Y' is [16 235]. The range of 'Cb' and 'Cr' are [16 240].

For the given image, one can find the mean values of the three components (Y, Cb and Cr) in YCbCr colour space as

$$Y_{mean} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} Y(x,y)$$

$$Cb_{mean} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} Cb(x,y)$$

$$Cr_{mean} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} Cr(x,y) \quad \ldots.(2)$$

Where $Y(x,y)$,$Cb(x,y)$ and $Cr(x,y)$ are Y, Cb and Cr components of the pixels at each spacial location(x,y). Y_{mean}, Cb_{mean} and Cr_{mean} are the mean values of luminance, Chrominance blue and Chrominance red components of pixels. M×N is the total number of pixels in the input image. Using mean of the image, one can find the standard deviation of the image in Y, Cb and Cr plane. Proposed method uses standard deviation of Cr plane. It can be determined as follows

$$Cr_{std} = \sqrt{\frac{1}{M \times N}\sum_{x=1}^{M}\sum_{y=1}^{N}(Cr(x,y) - Cr_{mean})^2} \quad \ldots(3)$$

IV. SEGMENTATION OF FIRE FLAME REGION

Rule I:

The rule defined in RGB colour space i.e, R > G > B can be translated in to YCbCr colour space as Y > Cb i.e, the intensity of Y component is greater than the intensity of Cb component. Hence Rule I can be explained as follows

$$R_I(x,y) = \begin{cases} I(x,y), & if Y(x,y) > Cb(x,y) \\ 0, & Otherwise \end{cases} \quad \ldots(4)$$

Where I(x,y) represents the input RGB image. Y(x,y) and Cb(x,y) are luminance and chrominance Blue values at different spacial locations (x,y). $R_I(x,y)$ is the pixel which satisfies Rule I. Fig. 3 shows the RGB input image and its corresponding Y, Cb and Cr components. The validity of rule I can easily been observed from the fire regions of fig. 4. That is, it is observed that intensity of Y component is greater than the intensity of Cb component.

Rule II

Since flame region is the brightest region in scene and chrominance red (Cr) component in the fire region is more, the mean values of Y and Cr channels in the overall image (Y_{mean} and C_{rmean}) contains valuable information. Table 2 shows**,** mean value of Y, Cb and Cr components of the image given in row 3 of fig. 2 (a) and also Y, Cb and Cr value of manually segmented fire region and non fire region. In fire region, the value of Y component at each spacial location is greater than mean value of the Y component (Y_{mean}) and the value of Cr component at each spacial location is greater than mean value of the Cr component (C_{rmean}). However, for the pixels in the non fire region one of these two conditions are not satisfied. These observations are verified over a number of experiments with images containing fire regions. From these observations Rule II is can be formulated. Rule II is applied on the pixels which satisfies Rule I.

$$R_{II}(x,y) = \begin{cases} R_I(x,y) & ,if Y(x,y) > Y_{mean}, Cr(x,y) > Cr_{mean} \\ 0, & Otherwise \end{cases} \quad \ldots(5)$$

Where, $RII(x,y)$ is the pixel in the input image which satisfies Rule I and Rule II. A pixel in the input image which satisfies Rule I and Rule II is considered as flame pixel. Fig 5 shows segmented image by applying Rule I and Rule II.

Table 2: Mean value of Y, Cb and Cr components

Row index	Y_{mean}	Cb_{mean}	Cr_{mean}
1	78	152	138
2	90	162	143
3	94	160	143

(a) (b) (c)

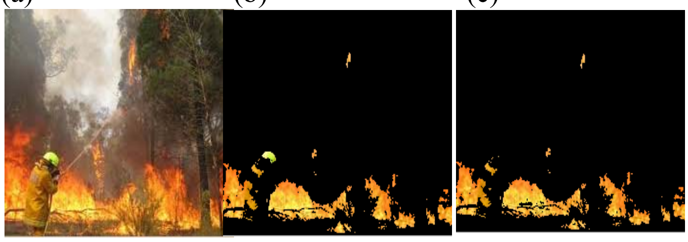

Fig. 5 (a) Input RGB image (b) Segmented fire region by using Rule I (c) Segmented fire region by using Rule II

V. SEGMENTATION OF FIRE CENTRE

Rule III

At high temperature, centre of the fire region is of white in colour. This gives the information that the chrominance red component is very less and chrominance blue component is more at the fire centre. To explain this idea many high temperature fire images are collected from the internet and their centers are analyzed. From the result, it is observed that at the fire centre luminance (Y) component is greater than the chrominance red component (Cr) and chrominance blue component (Cb) is greater than luminance component (Y). Based on this observation of large number of test images Rule III can be formulated as follows.

$$R_{III}(x,y) = \begin{cases} I(x,y), if Cb(x,y) \geq Y(x,y) > Cr(x,y) \\ 0 \quad otherwise \end{cases} \quad \ldots(6)$$

Where $R_{III}(x,y)$ indicates any pixel that satisfies the condition given in Eqn. (6). $I(x,y)$ is the input RGB image.

Rule IV

While segmenting the fire centre based on luminance, some of the white coloured regions like cloud and smoke are segmented from the input image. To overcome this problem, the texture of the fire region is also incorporated. Fire and the non fires like clouds have different textures. Texture of the fire region can be defined by the statistical parameters of the image like mean, median, standard deviation etc. In the proposed method standard deviation of the image for the Cr plane is incorporated i.e., Crstd. This observation is verified for countless experiments with images containing high temperature fire. This idea can be implemented by using Rule IV. Rule IV is described as

$$R_{IV}(x,y) = \begin{cases} R_{III}(x,y) \quad , if Cr < \tau \, Cr_{std} \\ 0 \quad otherwise \end{cases} \quad \ldots(7)$$

Where $R_{IV}(x,y)$ indicates any pixel that satisfies the condition given in equation (5). '$\boldsymbol{\tau}$' is a constant. The value of '$\boldsymbol{\tau}$' is determined by the analysis of image set consisting of 1000 images. Fig 7 shows few samples from this set. In fig.7 there are variety of images with different illumination and lighting. Furthermore the images are selected so that fire centre like coloured objects is also included in the set. For instance cloud in the image produces fire centre like colour (cloud). There are some images in a set which do not contain any fire. Based on the analysis conducted on the image set $\boldsymbol{\tau}$ value is selected as 7.4. Fig 8 shows segmentation of fire centre by using Rule III (Fig. 8(b)) and Rule IV (Fig. 8(c)). Cr_{std} is the standard deviation of the input image in Cr plane and is calculated by using Eqn. (3).

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. To get the true fire region, fire flame region and fire centre region must be combined. 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 which results by satisfying Rule I and Rule II another one which results by satisfying Rule III and Rule IV. Fig 8 shows the segmentation of true fire region from the input image using all the four rules.

Fig. 6 Images used to find the value of '$\boldsymbol{\tau}$'.

Fig 7. (a) Original RGB image (b) Segmentation of fire fire centre pixel using Rule III (c) Segmentation of fire centre pixel using Rule IV.

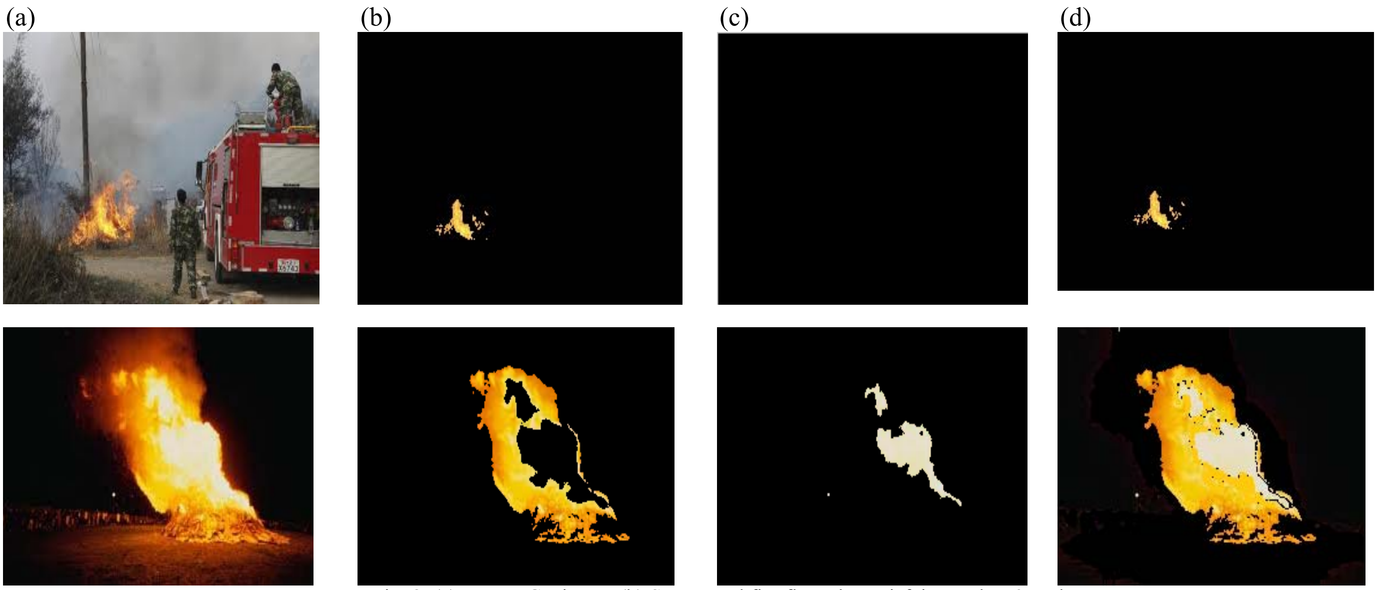

Fig. 8. (a) Input RGB image (b) Segmented fire flame by satisfying Rule I & Rule II
(c) Segmented fire region by satisfying Rule III & Rule IV (d) Segmented fire region by adding (a) and (b)

VI. PERFORMANCE EVALUATION

Performance of the proposed fire detection system is compared with the models defined in [1, 4, 8, 9, 10]. The model defined by Chen et al. [1] uses RGB colour space and rules are formed in RGB colour space. Celik et al. [4] uses rgb values to identify the fire region. Turgay Celik et al. [8] uses YCbCr colour space to segment the fire flame pixel from the RGB image. But all the above discussed methods do not separate the high temperature fire pixels in the fire centre region.

Analysis is carried out using more than thousands of images. This fire set consists of flame like objects such as sun, red coloured car, red rose etc. Table 3 shows fire flame detection rates of other methods and the proposed method. Celik et al. proposed a method which uses rgb values that shows better detection rates than the method proposed by Chen et al.using RGB values.

Table. 3 Performance of the proposed method and other four methods mentioned in the literature

Colour model used	Statistical parameters used	True detection rate	False detection rate
RGB[1]	-	0.939	0.664
rgb[4]	-	0.97	0.584
YCbCr[8]	Mean	0.99	0.315
RGB,YCbCr[9]	histogram & Mean	0.99	0.14
Proposed	Mean & Standard deviation	0.994	0.12

Turgay et al. [8] proposed a method using YCbCr colour space that produces improved detection rate. Vipin V [9] proposed a model to segment the fire from the image which uses RGB and YCbCr colour space. This method is not reliable under all situations. The proposed method effectively segments fire flame and the high temperature fire centre (white coloured region) with high detection rate and low false detection rates.

VII. CONCLUSION

In this paper image processing based fire pixel classification using YCbCr colour space is proposed. The proposed system uses YCbCr colour spaces. Because YCbCr colour space separates luminance from chrominance, hence it is robust to changing illumination than other colour spaces like RGB and rgb (normalized RGB). The proposed method not only separates fire flame pixels but also separates high temperature fire centre pixels by taking in to account of statistical parameters of fire image in YCbCr colour space like mean and standard deviation. It uses four rules to classify the fire pixels. Two rules are used for segmenting the fire flame region and two rules are used for segmenting the high temperature fire centre region. The proposed method is tested on three set of images. First set contain fire. Second set contain fire like regions. The third set contain fire centre like regions. Computational complexity of the proposed system is very less, hence it can be used for real time forest fire detection. The proposed system achieves 99.4% fire detection rate and 12% false alarm rate. The proposed method was compared with other methods in the literature and demonstrates superior performance in terms of higher fire detection rate and less false alarm rate.

The performance of the system can further improved by considering the motion characteristics of fire flame like fire movement, fire flicker etc. Furthermore, from the segmented fire region one can find the fire spread using geometric parameters of the fire flame (position, rate of spread, fire height fire length, fire inclination angle, fire base width, surface, volume).Visualization of fire spread is very useful for fire fighters.

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