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Detection of Fire Regions from a Video Image Frames in YCbCr Color Model

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Abstract*: Proposed here is a fire region detection method from a recorded video captured during the occurrence of fire. This method is based only on the chrominance components of the YCbCr color model. To distinguish the fire-region in an image frame of fire video containing the fire region, the difference between Cr and Cb is computed. The difference is enhanced by computing the square of it and then normalize range of difference squared to 0 to 255. It is then binarized at using automatic thresholding method to segment the fire region from the non-fire region. The fire region in the binary is located using the connected component analysis and the region is mapped to the original image frames of the fire video. We have tested the method in the actual fire video and it is found that the method can appropriately locate the fire regions in every image frame of the video. The method is simple and fast and hence can be used to forest fire monitoring using drones.

***Keywords*: Chrominance, Color model, Fire-Region Detection, Forest Fire Detection, RGB, YCbCr.**

I. INTRODUCTION

Forest fire occurs quite often in various countries around the world. It is very devastating if not intervened or controlled at appropriate time causing a huge loss to the forest resources and even to human habitations. With the development of technology, many scientists and researchers have been trying to find an effective and viable solution to detect forest fire so that occurrence or spread of forest fire can be prevented. Some use sensor based technology [8] and some use UAV and remote sensing techniques [5], [13], [16] and some other uses image processing based techniques [14]. The problem of sensor based Fire detection system is that it requires large number of sensors to cover a large area and also requires to wait for some conditions to trigger the sensors [9]. Another method considered viable for forest fire detection is the image processing based methods [2], [3],[4]. Most of the image processing based fire detection system is based on color analysis of fire region. Chen [4] uses RGB color information to develop a set of rules to classify fire pixels. In [12], [15], the fire region in an RGB image is detected based on the two assumptions or observations from the study of the 100 fire sample that in a fire pixel, Red value is greater than Green value and Green value is more than Blue value, i.e.(R>G>B). Some used normalized RGB to eliminate the effect of lighting variation in RGB. But this assumption may not be true, if that is so the chrominance components of YCbCr color model which consists mainly of Red (Cr) and Blue (Cb) components would not suitable to detect fire regions because green component is missing from chrominance components. In [2], it is inferred that Cr>Cb assuming that R>G>B and formed a rule to classify an image pixel as fire or non-fire. In [10] four rules based on YCbCr color model have been proposed to detect fire region in an image. The first two detects low intensity flame regions and the last two rules for high intensity flame regions. In [3], [7] a fire detection method from a fire video based on CIE L*a*b color model and motion detection. The method is based on background subtraction to separate the moving objects from the unmoving parts then used the perceptually uniform color representation of L*a*b to determine fire pixels from subsequent frames. In [7], after separating the moving and unmoving parts from video frames using CIE L*a*b, special wavelet analysis is used to differentiate between actual fire and fire-like moving objects and then support vector machine is used to classify the fire and non-fire regions. A fire detection method from video using YUB color space is suggested in [6]. In [1], various methods and techniques used for detection of forest fire have been discussed. In [11] presents the comparative analysis of five recent vision based fire detection system and a fire detection system based on LUV color space and hybrid transforms is proposed.

In this paper, we propose a simple fire detection method based only on the chrominance color of the YCbCr model unlike in [2] and [10] in which both luminance and chrominance components are used to detect fire regions. Here, we increase the variance of the chrominance to make the fire regions more prominent than rest of the image and then segment the fire region through automatic binarization. It has been tested on fire video and it is able to detect appropriate fire regions in the video frames.

II. SUITABILITY OF YCBCR MODEL

A. RGB Model

RGB color model is an intensity based additive color model suitable for display devices. It has three color planes based on intensity of the Red, Green, and Blue colors at each pixel location. Each color plane has the full scene of the image. This makes separation of region in the image corresponding to certain specific colors.

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Fig.1 shows the original image frame in RGB. The intensity images corresponding to the three color planes of the original image in Fig.1 are shown in Fig.2(a), Fig.2(b) and Fig.2(c). Each of these color components has almost the same information of the original image except the color information.

Fig.1: Original image

Fig.2(a): Red component of Fig.1

Fig.2(b): Green component of Fig.1

Fig.2(c): Blue Component of Fig.1.

For this particular image, red component has more prominent region of the fire region as compared to green and blue component. As all background objects in the image appears in each of the color components, segmenting the fire regions from any of such color planes is a difficult task.

B. YCbCr Model

YCbCr color model separates the intensity model of RGB image into luminance Y and chrominance components (Cb and Cr). The chrominance components contain the color information of the image, while the luminance component contains the intensity information. These chrominance components have mainly the color components of the fire regions and devoid of other non-fire regions. The fire-region has specific color which can be easily identified and located in the Cb and Cr components. The luminance (Y component) is show in Fig.3(a) and the chrominance components are shown in Figures 3(b) and 3(c) respectively.

Fig.3(a): Intensity (Y) component of Fig-1

Fig.3(b): Cb Component of Fig.-1.

Fig.3(c): Cr component of Fig.-1.

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It can be seen that most of the background information is lost in the images of the chrominance components of Fig.3(b) and Fig.3(c).

In these chrominance images, only the fire regions stand out different from the rest areas of the image. From such chrominance images, separating or locating the fire regions becomes easier.

III. COLOR DIFFERENCE OF CHROMINANCE

Separating fire regions from the image frames directly from the chrominance components is not very convenient as still there are shades of other regions in these components. However, if we use difference of the chrominance components, we can suppress most of the unwanted background regions and at the same time enhance the fire-regions in the resulting image. In the case of YCbCr image the difference of Cb component from Cr component gives more distinct fire region than difference of Cr from Cb. Fig.4 shows the image obtained from the difference of Cb component from Cr component. It can be seen that most of background regions outside the fore regions are removed and fire regions become more distinct. Note that Cr component has larger values than Cb component values in fire regions, so if we display difference image of Cb-Cr, the fire regions will be lost.

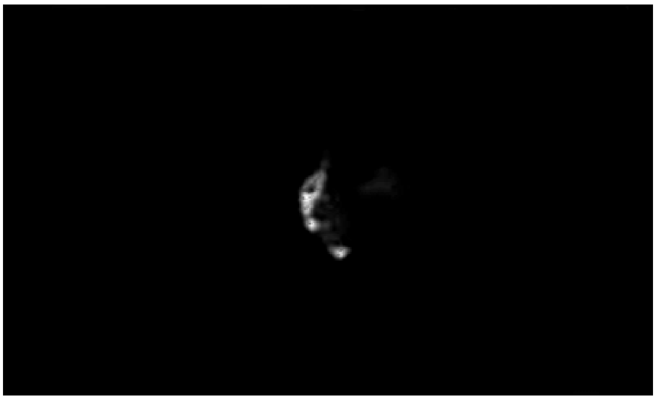

Fig.4: Cr-Cb Image

IV. FIRE REGION DETECTION

The color difference image is not in binary even though it quite clearly shows the fire regions. In order to map the fire region in the original image, we need to locate the region in the difference image. So, the difference image is to be binarized at appropriate threshold to segment the fire region from it. Choosing an appropriate threshold to directly is a difficult task for binarization. To simplify the process of choosing threshold, we increased the variance of the difference image further by squaring the difference image. The threshold is chosen automatically from the non-zero pixel values such that which has minimum value. To determine the appropriate threshold, we compute the histogram of the non-zero pixels and then choose the pixel value corresponding to the minimum point or valley in the histogram.

Let $n_1, n_2, n_3, \cdots, n_K$ are K different non-zero pixels in the difference image. Then, the threshold n_T to binarize the difference image is chosen as follows.

$$P(n_T) < P(n_i), \quad \forall n_i \neq n_T \tag{1}$$

Where P(i) denotes the number of pixels having the value i.

In the case of multiple values of thresholds, then the final threshold is chosen as the average value thresholds i.e,

$$P(n_{T1}) = P(n_{T2}) = P(n_{T3}) < P(n_i), \forall n_1 \neq n_{T1} \neq n_{T2} \neq n_{T3}$$

$$n_T = (n_{T1} + n_{T2} + n_{T3})/3 \tag{2}$$

Using "(1)" and "(2)" we can automatically binarize the difference image to segment fire-region as white region and non-fire regions as black region.

Once the fire region is segmented, the fire region is increased by about 3 pixels all round by using image dilation so that any missing nearby fire regions are also got captured in the fire region. Then, the location of fire region in the image is computed by finding the white region using connected component analysis. To compute the rectangular area containing the fire region, we compute the minimum and maximum row and column coordinates of the white fire region in the dilated binary image. If $r_{\min}$, $r_{\max}$ are the minimum and maximum row co-ordinates; $c_{\min}$ and $c_{\max}$ are the minimum and maximum values of the column co-ordinates of the fire region, then pixel values within the block of rectangular area defined by the four co-ordinates $(r_{\min}, c_{\min})$, $(r_{\max}, c_{\min})$, $(r_{\min}, c_{\max})$, $(r_{\max}, c_{\max})$ contains the fire region.

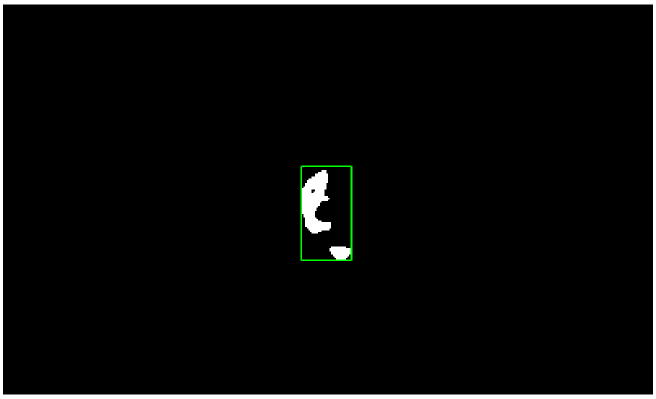

Fig.5: Fire Region mapped with Cr-Cb color difference

Fig.5 shows the rectangular fire regions located in the binary image generated from the color difference image shown in Fig.4. The binary image in Fig.5 can be obtained from Cr-Cb image at lower threshold value 65. But to avoid manual selection of threshold, we will use automatic threshold selection rule described in equation (1) and (2).

Once the rectangular region containing the fire region is identified in the image, the actual fire region can be located in the original image frame. We first find the co-ordinates corresponding to the fire regions in the binary image. Then a zero image having the same size as the binary image is created. In the zero image, which is totally black image, the fire region is replaced by the actual fire pixels extracted from knowledge of fire-region co-ordinates, i.e. row and column indices. Fig.6 shows the fire region extracted from the original fire image shown in Fig.1.

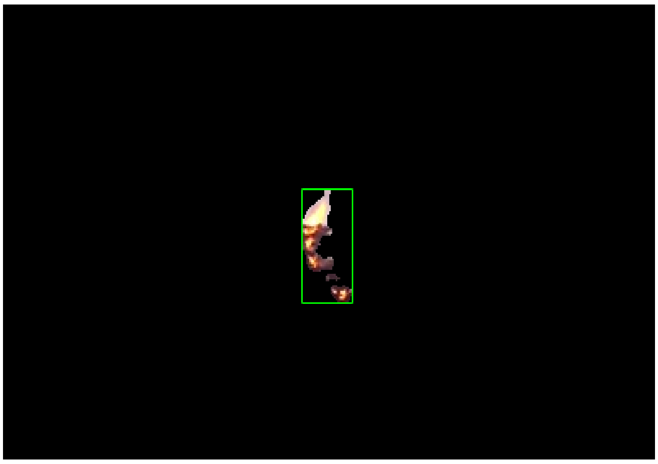

Fig.6: Extracted fire region from Fig.1.

V. Experimental Results

To detect fire regions from a video recording capturing the forest fire, we first extract the image frames from the video file. Then, fire region is detected from each image frame. The rectangular region containing the fire is found out by specifying the top leftmost corner point of the rectangle, and width and height of the rectangle. The topmost left corner corresponds to the minimum row and column index of fire region. The width and height corresponds to the difference of maximum column index and maxim row index from the minimum column and row index of the fire region.

For experimentation, we use the fire video downloaded from the link [17]. The video is of short duration having about 635 frames. We have tested all frames for fire regions and the fire regions are detected correctly as expected. We have extracted the location of the fire regions of the frames. The location of first 50 frames are given in Table-I. The first row corresponds to the first 10 frames, the second row corresponds to the next 10 frames and so on. In the table, the fire region is specified in four numbers in each cell – the first two corresponds to the co-ordinates of top-left corner of the rectangular region. The third number corresponds to the width of the rectangle and the fourth to the height..

Table- I: Rectangular regions in first 50 frames of fire video

183, 99, 33, 60	183, 97, 33 , 62	183, 97, 33, 62	183, 97, 33, 62	183, 103, 32, 56	183, 103, 32, 56	183, 102, 32, 57	183, 102, 32, 57	183, 101, 32, 58	183, 101, 32, 58
183, 105, 32, 54	183, 106, 33, 53	183, 105 , 33, 54	183, 105, 33, 54	183, 105, 33, 54	183, 105, 33, 54	183, 105, 33, 54	183, 104, 33, 55	183, 103, 33, 56	183, 102, 33, 57
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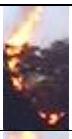
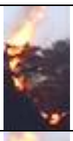
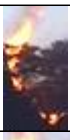
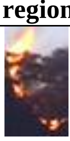
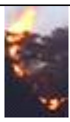
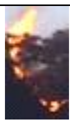
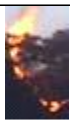
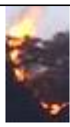
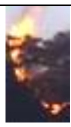
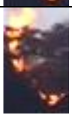
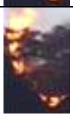
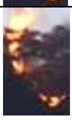
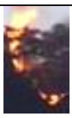
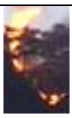
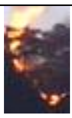
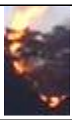
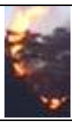
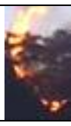
184, 109, 31, 50	183, 109, 32, 49	183, 109, 32, 49	184, 109, 31, 49	183, 110, 32, 48	183, 109, 32, 49	183, 110, 32, 48	183, 109, 32 , 49	183, 109, 32, 49	183, 109, 32, 49

Table-II: Extracted fire regions from the first 50 frames of the fire video.

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The entry at cell the first cell (i.e., 183, 99, 33, 60) means the rectangular region at column number 183 and row number 99 having the width of 33 pixels and height of 60 pixels. From these knowledge of locations of the rectangular fire regions, the actual fire region in each image frame can be extracted. The cropped fire regions from the original fire frames according to the rectangular regions specified in Table-I are given in Table-II. It may be observed that the fire regions in the video frames are appropriately extracted from each frame. The method is simple and fast and can be used for real-time fire detection system.

VI. CONCLUSIONS

A Simple, fast and effective method of detecting fire regions from an image or video has been suggested. The method uses the difference in chrominance components to distinguish the fire regions from the non-fire regions in the image. Then, fire region in the image is then located through binarization and connected component analysis. The actual fire regions in the video frames are extracted from the knowledge of their locations in each frames. The method works perfectly to locate fire regions when applied to a fire video downloaded from internet. As the method is fast, it can be implemented for real time detection of forest fire.

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Yumnam Kirani Singh, has completed Master's Degree in Electronics Science from Guwahati University in 1997 and got Ph. D. degree from Indian Statistical Institute, Kolkata in 2006. Served as a lecturer in Electronics in Shri Shankaracharaya College of Engineering & Technology from Jan, 2005 to May, 2006. Joined CDAC Kolkata in 2006 and worked there before coming to CDAC Silchar, in March 2014. Developed Bino's Model of Multiplication, ISITRA, YKSK Transforms, Generalized Vigenere Cipher, Meitei Lock Sequence, and several other image binarization and edge detection techniques.

Interested to work in the application and research areas of Signal Processing, Image Processing, Pattern recognition and Information Security. Published several research papers in national and international journals and conferences.

Mr. Debasish Deb, completed his M-Tech from NIT Agartala in May 2015 and joined C-DAC Silchar in August 2015. Since then he has been working in C-DAC in various design and development projects and Capacity Building in the North East. He also worked in SCADA Communication protocols and Real Time Energy Assessment System projects. He was also involved in the development of Drug and Vaccine Distribution Management System. Currently, he is working in a project entitled "Development of Forest Fire Detection System and Pilot deployment in North Eastern Indian States". He has published 3 research papers both in national and international conferences/journals. His current interests are Image Processing and Deep Learning.