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Detection of Fire Regions Using RGB Color Variance

Yumnam Kirani Singh
C-DAC Silchar, Ground Floor, IIPC Building, NIT Silchar Campus, India

Abstract
The flames of any fire have some specific color range depending on the type of material being burned and the heat generated in the fire. The fire flames have no specific shapes which can be computationally used to distinguish it from non-fire objects or surrounding. As a result of which, color range of fire flames has been used to identify or detect fires computationally. Some researchers use different color models to represent the color for convenience of analysis. Some of the color models other than RGB used for detection of fire region in an image are YCBCR, CIE etc. In most of these fire detection methods, many different rules based on separate color components have been used to define fire regions. In this proposed method, some new approaches based on variances, standard deviation, covariance of RGB color components have been used. It has been found that the variances and standard deviation approaches are most effective to correctly identify most of the fire regions from the surrounding non-fire regions in a fire image. The method is simple and fast and can be conveniently used IoT based device for real-time fire detection.

Keywords: *Fire Detection, Flame Detection, RGB Color Variance, Color models, real-time fire detection.*

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I. INTRODUCTION

Fire causes irreparable loss of property or resources if not controlled at appropriate time. In the last two decades, several incidences of occurrence of devastating forest fires have been reported across the world which causes a huge loss to the forest resources and even to human habitations. The best way to avert the loss due to fire is to detect the fire at the early stage and douse it. Considering the vastness of forest area, it is almost impossible to keep monitoring all regions and all time for occurrence of fire, although watchtowers were installed in some specific forest regions. Alternative way is to develop a machine or device for monitoring the occurrence of fire day and night throughout the years. Many scientists and researchers have been searching such an effective and viable solution to detect forest fire so that occurrence or spread of forest fire can be prevented in time. Of many solutions for fire detection, detection of fire using image processing seems to be more feasible and economical solution. So, many image processing based forest fire detection methods have been proposed. Some methods try to detect fire from single image, some methods try to detect fire from a sequence of images of a video. In most of the methods, it is mentioned that RGB image captured by digital or video camera is not suitable to detect fire regions. In these methods, the original RGB image is converted into a suitable color model before proceeding the fire detection process. Of all the color models, YCbCr is popularly considered to be more suitable for fire detection as it has separate luminance and chrominance components. In [5] 18 different color models were studied based on Bag of Features method to compare the classification accuracy and fire region separability. It is concluded that Srgb and PJF are better than other color models.

In [2], the RGB image is converted into YCbCr color model to identify fire pixels based on the assumption that in fire region the pixels the Y component is greater than Cr component which is greater than Cb component. It then applies 16 different fuzzy inferential rules to identify the most probable fire pixels. In [4], two color models CIE L*a*b and YCbCr are used. It generates two different outputs of segmented fire regions- one output of segmented fire regions using K-means on CIE image, and the other output of segmented fire regions from the YCbCr color model based on variance and standard deviations. The two segmented outputs are then merged to get the final detected fire regions. It is claimed to give better results than the generic fire model proposed in [3]. Other methods that use YCbCr color models are found in [8, 10, 12]. In [8], YCbCr color model is used to find fire regions from images of video frames. It first subtracts the successive frames to detect motion. If any motion is detected, the current image frame is converted YCbCr color model and apply five different rules to detect fire region. Also, it computes temporal variations of the fire region to determine if it is fire region or a fire like objects. In [10] YCbCr color model and uses four different rules. The first two rules are used to segment the fire pixels, and the last two rules to segment the high temperature zone in the fire region based on standard deviation and mean. In all these rule-based YCbCr methods, all the components i.e., the Y, Cb and Cr components are used to detect fire region. However, in [12] only on the chrominance components, i.e., Cb and Cr components are used. To distinguish the fire-region in an image frame of fire video containing the fire region, the difference between Cr and Cb is computed and the squired to enhance difference and then normalized to 0 to 255. The normalized image is binarized using automatic thresholding method to segment the fire region from the non-fire region.

Some methods use statistical an machine learning methods for detection of fire region [1, 6, 7, 9,11]. In [6], a new differentiating color conversion matrix is formed based on K-Medoid clustering and Particle Swarm Optimization procedures from fire image to reduce false fire alarms, i.e., false negative in color based fire detection methods. In [7], motion detection and color detection are applied as preprocessing stage to identify probable fire pixels. Then it computes the centroid of flame region and construct a spatiotemporal image. Three different variability features i.e., Spatial variability, Shape variability and Area variability are extracted and fed to a Support Vector Machine to classify a frame of video as fire or not. In [9], the moving and unmoving parts from video frames are separated using CIE L*a*b. Then, 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. In [11], a deep learning method has been attempted to detect fire region. It is complex and time consuming process to get a good classifier. So, far only 76% accuracy could be achieved using this method. In [1], deep convolutional neural network is used to extract features from the image frames of a video which are then used as inputs to logical regression for detection of fire pixels.

In this paper, a new method of fire detection based on the variance of RGB color pixels is proposed. In this method, a variance image is formed by variance of each RGB color pixel. This makes the original RGB image which three different color component is converted into single plane image having only color variance. In other words, the 3-D RGB array is converted into a 2-D array of variance. Processing 2-D array is much easier and taking less memory than processing the original 3-D array. Moreover, the color variance is much higher for fire pixels than non-fire pixels. As a result of which fire regions can be effectively segmented from the non-fire regions in an image.

II. IDENTIFICATION OF FIRE PIXELS

Variance of a data sequence gives mean of square of difference of the elements from the mean. The standard deviation is the square root of the variance. It has been observed that the variance of RGB pixel corresponding to fire region is considerably higher than non-fire pixels. This makes the fire regions easily distinguishable from the non-fire regions in resulting variance image. Figure-1(a) shows the original fire image whose variance image is shown in Figure-1(b). If we compare the two images, it may be easily seen that the whiter parts in the variance image correspond to the fire regions and the darker parts correspond to the non-fire regions. The variance image is the 2-D array as compared with RGB which is a 3-D array. As a result of which separation of fire-region from the variance image can be done by binarizing the image at an appropriate threshold. In other words, the fire regions in the resulting variance image can be effectively separated from the non-fire regions. So, once we get the variance image of an RGB fire image, we can separate the fire region from the non-fire regions. The Algorithm for separating or detecting the fire regions from non-fire regions in an image is given below.

Figure-1(a): Original Image

Figure-1(b): Variance Image

Algorithm for Fire-region Detection

1. Read the image
2. Find the number of rows and columns in the image
3. For each pixel in the image,
   Compute the variance of red, green and blue values
4. Change the range of the values in the variance image to 0 to 255

5. Binarize the variance image at proper threshold to separate the fire regions from non-fire regions
6. Get the RGB values of the original image corresponding to the fire region in the binary image
7. Display the extracted fire regions from the original image.

The algorithm starts with reading the fire-image in step-1. After reading the image, the size of the image i.e., the number of rows and columns in the image is found out in step-2 which is required to access each RGB values of the pixels in step-3. Step-3 computes the variance of the red, green and blue values at each pixel location which is a scalar value. Thus, the 3-D array of the RGB image is converted to 2-D array as variance image. In this step, instead of variance, standard deviation may be computed. However, there will be significant difference in the range of 2-D array generated by using variance and the standard deviation. The range of 2-D array generated by using variance is much larger than by using standard deviation and is much beyond the 0 to 255 range. So, the resulting 2-D array in step-3 is range normalized to 0 to 255 in step-4. That is, in step-4 the variance matrix becomes a gray image which is then binarized in step-5 to separate the whiter regions corresponding to fire regions from the non-fire regions. As the fire regions is quite distinct, binarization can be done by simple thresholding method making all pixels greater than threshold to 1s, and the other pixels to 0's. After binarization, the resulting binary image will have white regions (i.e., 1's) in the fire regions and 0's in the non-fire regions. In order to extract the fire-regions in the original RGB image in step-6, each color plane is multiplied with the binary image in step-5. This makes all the RGB pixels corresponding to non-fire regions to black and keeps the fire region intact. The extracted fire-region is then displayed (step-7).

It may be noted that the proposed method described for fire-region detection is simpler than rule base methods which require many comparison operations in different color planes. Moreover, it is very effective in detecting fire regions in an image.

III. EXPERIMENTAL RESULTS

To test the proposed algorithm for fire region detection, several different fire images have been collected from the internet. The algorithm is directly applied to the collected images. The algorithm is found to detect the fire-regions in most of the images including some non-fire regions in some of the images. The threshold values in the range between 60 – 150 is appropriate in most of the fire images collected so far. The lower threshold value covers the fire regions in the low intensity range. If the threshold value is higher, it covers only the high intensity fire regions. Although the algorithm detects fire regions in fire images, in some images it also detects non-fire regions as fire regions which is false positive. For fire detection false positive is good from the safety point of view. However, too much of false positive will be annoying to users. Fire images and their corresponding extracted fire regions are shown in Figures 2 to 6. From the figures, the fire regions are properly extracted. However, in the extracted fire regions of the Figure-4(b), 5(b) and 6(b), non-fire regions are also extracted. In figure 4(b), a small part of the yellow head of a fire extinguisher and the yellow fire extinguisher pump are also seen. In figure 5(b), a small part of yellow shirt of a person running towards the fire is also extracted. Similarly, a majority of the reddish sand dune in the fire-image of figure-6(a) is also extracted in figure-6(b). On pixel analysis of those extracted non-fire regions, it is found that the pixel statistics of the non-fire region and the fire region are similar. Hence the non-fire region is also detected as fire regions. These extracted non-fire regions are much smaller in size as compared with fire region and these can be eliminated by filtering out the smaller fire regions from the extracted fire regions.

Figure-2(a): Fire Image

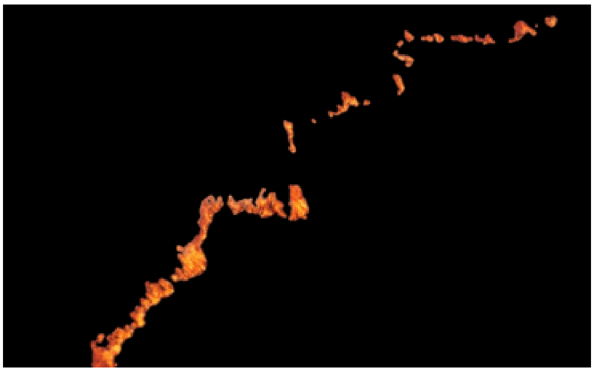

Figure-2(b): Extracted Fire Region

Figure-3(a): Fire Image

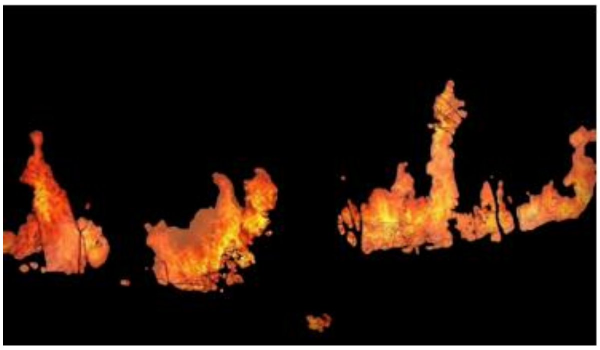

Figure-3(b): Extracted Fire Region

Figure-4(a): Fire Image

Figure-4(b): Extracted Fire Region

Figure-5(a): Fire Image

Figure-5(b): Extracted Fire Region

Figure-6(a): Fire Image

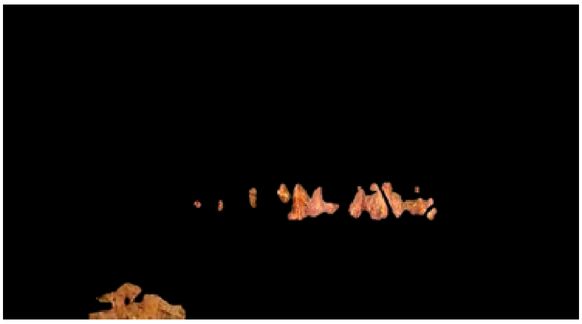

Figure-6(b): Extracted Fire Region

IV. CONCLUSION

A new simple and effective method for fire region detection in an image based on color variance is proposed. It is based on observation that the variance of red, green and blue components of fire-pixels is significantly different from the pixels from the non-fire pixels. The method can detect the fire-regions in an image. The algorithm proposed is fast and can be implemented for real-time fire detection in resource constrained embedded system devices. The standard deviation of the red, green and blue components of RGB color image can also be used effectively with the little more complexity of performing square root of the variances of each color pixels.

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