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A New Color-based Segmentation Method for Forest Fire from Video Image

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***Abstract*—This paper proposes a new color-based method for forest fire segmentation from video image. Two kinds of color features including intensity value and color distribution are used. In segmentation based on V value of HSV color model, the lower threshold is defined from experience, and the higher threshold value is computed automatically, thus the possible fire regions can be divided into two subsets accordingly. In segmentation based on color distribution, fire color samples are collected and then projected onto HS, HV and SV planes. One pixel can be decided as fire or not quickly by checking whether its color values lie within the distribution ranges of the three 2D planes at the same time. Final fire regions are generated from these two segmentation results. Our method is tested on some video images with fire and the results are encouraging.**

Keywords-forest fire; image segmentation; HSV model; color distribution

I. INTRODUCTION

Many countries in the world are committed to research and development of fire detection methods and equipments that can forecast fire disasters in the early time. There are fire sensors already used for particle, temperature, smoke and relative humidity, but the detectors either must be set in the proximity of the fire place or can't provide the additional useful information about the process of burning, such as fire location, size, growing rate, and so on. To provide more reliable information about fire, the visual-based approach based on video images is receiving more and more attentions from the researchers [1,2].

For fire detection from monocular images or video, some typical features of fire, such as area, roundness, contour, etc. are often used. Fire area is represented by the set of fire pixels. To identify a fire's growth feature, size variations of fire area are calculated from consecutive images [2]. If the result is more than a predefined threshold value, there is a likely fire's growth. Given a segmented region, its boundary can be retrieved using a classical Laplacian operator [3] and then it is convenient to retrieve its eight-connected boundary chain code [4]. From the chain code, the perimeter of the boundary can be easily computed. Based on the perimeter and the area of the region, its roundness can be calculated, which describes the complexity of the shape, more complex shape has greater value. Roundness can help to get rid of the inerratic bright subjects in the early time. Since the shape of fire or smoke is changeable owing to air flowing, the contour fluctuation can be computed to measure the disorder. For the points lying on the boundary, the coefficients of the Discrete Fourier Transform [5] of them are calculated, and then a few dozens of the Fourier coefficients are used to describe the property of contour.

Image segmentation is the first and most important step for the fire features. Only when the target area is correctly segmented from the image, can the features be calculated effectively to detect fire or smoke. T. Celik et al. [6] described the color features of fire in RGB color space, and gave some rules to decide whether one pixel p_i belongs to the fire region.

$$\begin{aligned} &R(p_i) > R_{mean} \\ &R(p_i) > G(p_i) > B(p_i) \end{aligned} \tag{1}$$

where $R(p_i)$, $G(p_i)$, $B(p_i)$ are R, G, B value of the image pixel pi, and R_{mean} is the average R value of all pixels in the image. Based on further study of fire color, another group of in-equations are added for fire decision.

$$\begin{aligned} &0.25 \le G(p_i)/(R(p_i)+1) \le 0.65 \\ &0.05 \le B(p_i)/(R(p_i)+1) \le 0.45 \\ &0.20 \le B(p_i)/(G(p_i)+1) \le 0.60 \end{aligned} \tag{2}$$

T.H. Chen et al. [7,8] tried to segment fire region from image in RGB color space. To avoid being affected by the background illumination, the saturation value of fire-flame extracted needs to be over one threshold in order to exclude other fire-similar aliases. Three decision rules are deduced for extracting fire pixels from an image.

$$\begin{aligned} &rule1: R > R_T \\ &rule2: R \ge G > B \\ &rule3: S \ge ((255-R)*S_T/R_T) \\ &IF \quad (rule1) AND (rule2) AND (rule3) \\ &THEN \quad fire-pixel \\ &ELSE \quad not-fire-pixel \end{aligned} \tag{3}$$

C.B. Liu et al. [9] studied color, geometry and motion of fire region for recognition, and modeled the fire region in a single image as follows: (i) it stands in high contrast to its surroundings; (ii) it exhibits a structure of nested rings of colors, changing from white at the core to yellow, orange and red in the periphery. The model is suitable for blazing fire as there are nested rings in color structure. But for our project of forest fire detection, there are early fire or the fire partially covered by smoke, where no nested ring exists at all.

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In our paper, a new color-based segmentation method is proposed for forest fire from video image. Both the intensity value of HSV color model and fire color distribution from sample images are used for segmentation. The paper is organized as follows: segmentation based on V value is introduced in section 2, segmentation based on fire color distribution is described in section 3, experimental results are provided in section 4, and then the conclusion is given in section 5.

II. SEGMENTATION BASED ON V VALUE

Compared with RGB color model, HSV (hue, saturation, value) color model is very suitable for providing a more people oriented way of describing the color, because the hue, saturation and value components are intimately related to the way in which human beings perceive color [10]. In the general point of fire [11], the flame usually has high intensity value and display reddish color, besides, the color of the flame will change with the increasing temperature. Therefore, HSV color model is adopted in our project and the video image is first segmented based on V value.

Two threshold value, V_{low} and V_{high}, are defined for V based segmentation. The lower threshold V_{low} is a constant value from our experimental experience, while the higher threshold V_{high} is a value computed automatically. Related with V_{low} and V_{high}, there are two subset of the video image: L, set of the pixels whose V value is no less than V_{low}; H, set of the pixels whose V value is no less than V_{high}.

$$\begin{aligned} L &= \{p_i \mid p_i \in [V_{low}, 255]\} \\ H &= \{p_i \mid p_i \in [V_{high}, 255]\} \end{aligned} \tag{4}$$

Obviously, H is a subset of L. If L is taken as the possible fire region, H can be used for further decision. For the number of pixels, the percentage of H in L can be controlled by a parameter α

$$\frac{Num(H)}{Num(L)} < \alpha \tag{5}$$

The smaller the α value, the less the number of pixels in H, together with the higher threshold value of V_{high}. The procedure for computation of threshold V_{high} is:

Step 1: Define the distribution function F(x) for subset L as

$$F(v(p_i)) = P(t \le v(p_i)) = \sum_{t=low}^{v(p_i)} f(t), low \le v(p_i) \le 255, p_i \in L \tag{6}$$

Step 2: Find the subset H based on F(x) as

$$H = \{p_i \mid F(v(p_i)) > 1 - \alpha\} \tag{7}$$

Step 3: Calculate the higher threshold value V_{high} as

$$V_{high} = \min(v(p_i) \mid p_i \in H) \tag{8}$$

III. SEGMENTATION FROM FIRE COLOR DISTRIBUTION

Besides high intensity value, fire color is another typical feature for forest fire segmentation. Color values of each pixel are compared with a predetermined color distribution [12], which represents possible fire colors in the video images in HSV color space. To simplify the computation, H, S and V are adjusted into the ranges of [0,255], [0,255] and [0,180] respectively. The fire color distribution is obtained from sample images containing fire regions, and the possible color values form a three dimensional point cloud, as shown in Fig. 1. Then the 3D shape of the point cloud can be represented by Gaussian mixture model, and the pixel whose colors within the range of the distribution model can be taken as a fire pixel.

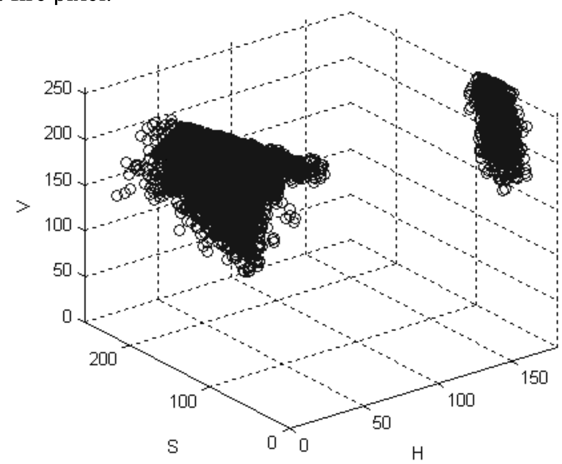

Figure 1. 3D point cloud of color distribution

To reduce computational cost, we use three 2D projection planes instead of the 3D distribution model. As shown in Fig. 2, fire colors from the sample images are projected onto HS plane, HV plane and SV plane. In each plane, the range of color distribution can be easily represented by one or two rectangles. Therefore, whether one pixel is fire pixel can be quickly decided by checking its color locations on the three 2D distribution planes.

IV. EXPERIMENTAL RESULTS

Methods of [6] are applied for video images with forest fire, as shown in Fig. 3. The 1st row shows the source images, the 2nd row shows the results from Eq. (1), and the 3rd row shows the results from Eq. (2). It can be found that Eq. (1) obtains many other regions with the similar color as fire, while only a few fire regions (surrounded by the box in the 4th image of the 3rd row) are obtained from Eq. (2).

Methods of [7] are also tested and the results based on Eq. (3) are shown in Fig. 4. Parameters R_T and S_T have to be adjusted manually, and they affect the fire segmentation obviously, especially for parameter S_T. The 2nd row displays the results from R_T=170 and S_T=0.9, while the 3rd row displays the results from R_T=170 and S_T=0.3.

Results from our method are shown in Fig. 5. The 1st picture is source image, the 2nd picture is segmentation result based on V value, the 3rd picture is result from fire color distribution, while the 4th picture is the union of these two kinds of segmentations: black pixels are background, dark gray pixels are segmented regions based on V value, light gray pixels are segmented regions based on color distribution, and white pixels are segmented regions from both of the two kinds of segmentations at the same time.

Some more pictures including forest fire and even building fire are used to test our method, as shown in Fig. 6. From the experimental results it can be found that our method has the ability to segment fire regions successfully from monocular video images.

V. CONCLUSION

For fire or smoke recognition from monocular video, image segmentation is the first and most important step, which affects the final results. We study the properties of forest fire and present a new color-based method for forest fire segmentation from video image. The picture is segmented based on intensity value of HSV color model and color distribution from sample images independently, and the final fire regions are generated from these two segmentation results. Our method are tested by video images with forest fire and building fire, and the results help prove that our approach can obtain better fire regions than those of the published color-based segmentation methods.

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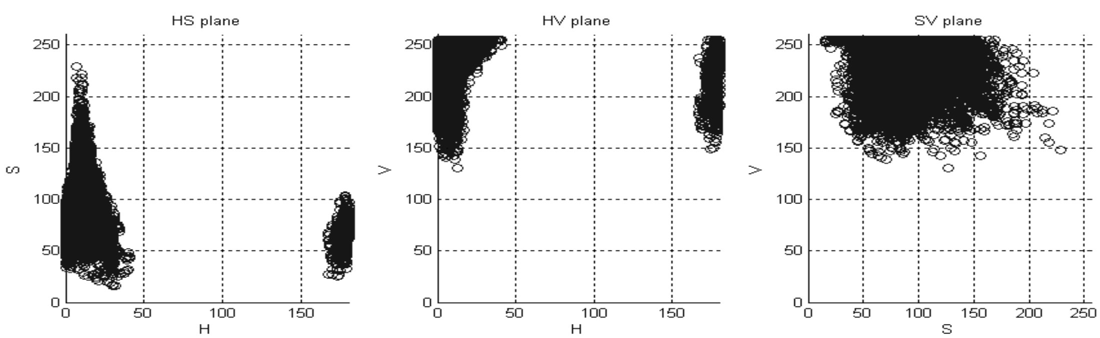

Figure 2. 2D projection planes of color distribution

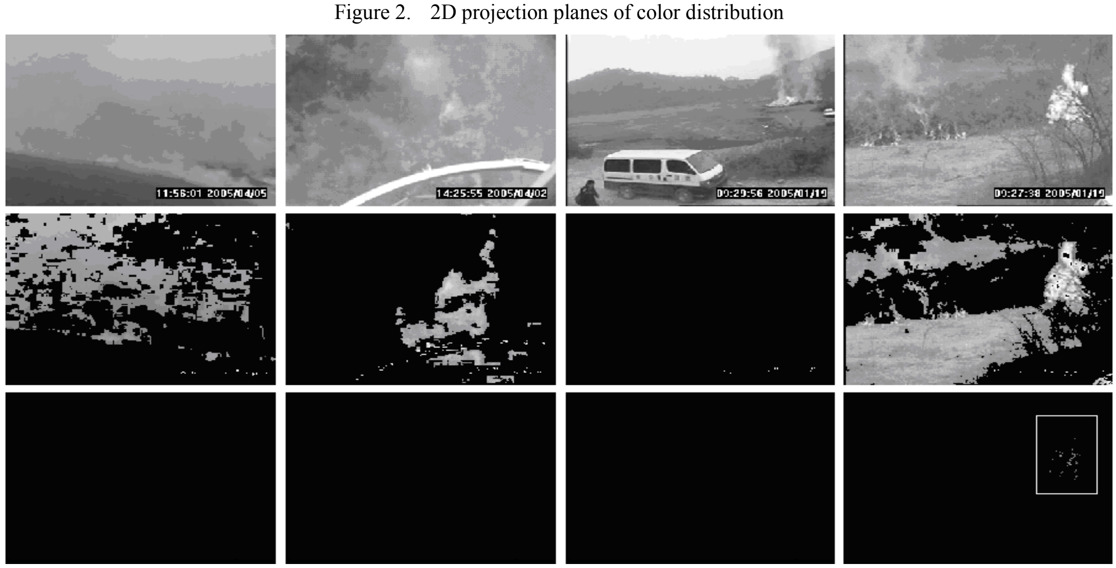

Figure 3. Segmentation results from [6]

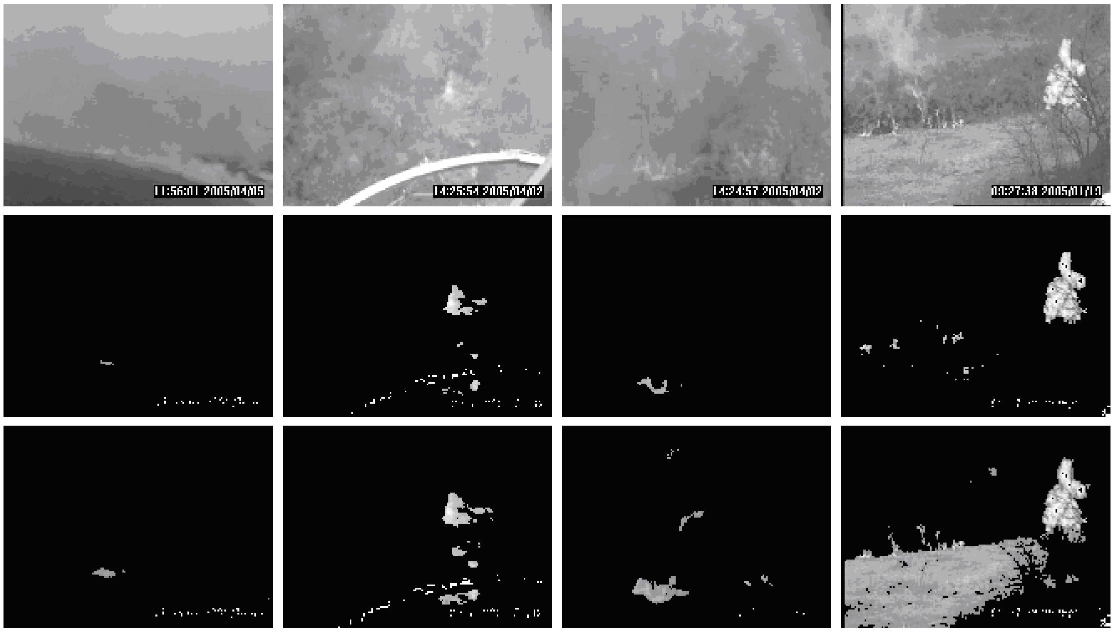

Figure 4. Segmentation results from [7]

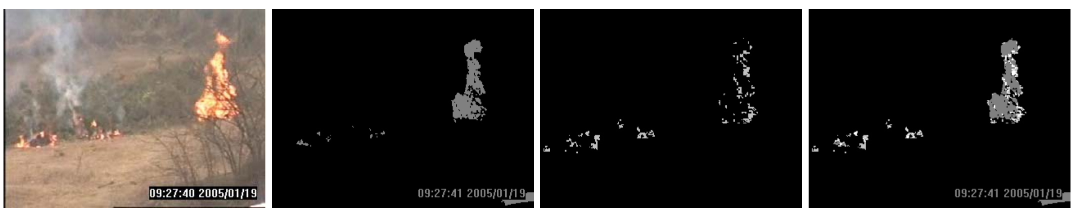

Figure 5. Segmentation results from our method

Figure 6. Some more experimental results