Vision Based Technique for Smoke and Fire Detection in Monitored Forest Terrain

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ABSTRACT

Forest fire and/or smoke detection problem is an urgent task as it harms ecology and decreases the overall life quality. In this paper, we examine the problem of fire/smoke detection using images of different parts of the controlled area of the forest. We propose an approach to solve the problem based on full segmentation, simplification and subsequent isolation of segments with and without fire/smoke. A new approach to transform the colored image components which affect the scene brightness to the final results is applied. The procedures of statistical analysis and data classification method are offered. Efficiency of the proposed procedures is shown.

Keywords

Fire, flame, smoke, segmentation, image processing, classification

1. INTRODUCTION

Forest fires are a threat for ecological system and have direct impact on human life quality and on ecosystem overall. That is why early fire and smoke detection appears to be an actual problem and there are a lot of scientific and technical works referring this problem.

Systems and methods of early smoke and fire detection are quite different [1]. It is known that many techniques, used for fire detection, are based on temperature, relative humidity, air transparency, photosensitivity and other physical characteristics [2]. But they are too bad to meet the needs in a large space, changing outdoor environment, weather conditions etc. Due to the slow spread of smoke and temperature, sensors may be delayed in detecting fire. Furthermore, sensors should be close to the fire. All these factors extremely degrade the practical efficiency of such kind of systems.

Due to the rapid developments in digital camera technology and developments in content based video processing, more and more vision based fire detection systems are introduced. As a pre-processing step in the detection of possible fire or smoke the color information is used.

The goal of present investigation is to develop a robust method based on image processing, that is able to detect fire or smoke in a large controlled area. The method must be fast enough for practical usage, i.e. be permissible to process large images and make decisions online.

In this paper, we assume that the incoming information is received from different parts of the area, which are considered as potentially fire-hazardous. Thus the appearance of fire or smoke preceding it in any part is regarded as an event that causes a rather significant change in image content, i.e. the pattern of distribution of the observed color characteristics. We also assume that at absence of these events the corresponding parts of the image are characterized by some type of texture which has a fairly homogeneous structure. In contrast, if there exist the areas containing fire or smoke, in image there will be observed certain connected parts having a specific shape and intensity distribution of the pixels in the selected color space.

Hence, the problem of smoke or fire detection means choosing such kind of image segments and their comparison with the segments obtained in the absence of fire or smoke. Thus, we come to the need to develop and apply the proper procedure of the color image segmentation in this problem.

2. RELATED WORK

In the scientific literature there are a lot of methods and approaches for the fire and/or smoke determination which are based on image segmentation procedures. We refer to some surveys [3] on this topic, but some articles contain ideas and procedures which are close to the present investigation, therefore we will briefly consider them.

Method for the detection of fire and smoke proposed in [2] is based on the usage of color spaces RGB and YCbCr. For the fire area pixel consistent pattern $Y > Cr > Cb$ is discovered. For the smoke detection the feasibility of the system of these three inequalities $|R - G| < Th$, $|R - B| < Th$ and $|B - G| < Th$ are checked, where Th is located between 15 and 25. However the application of this method in our investigation directly is impossible, when the brightness of the monitoring area is nonhomogeneous.

Article [4] contains some improvement of the method, used in [5], consisting of clarification of the mean values for the color component RGB, taking into account the mean values of components Y_{mean}, Cr_{mean}, Cb_{mean} , adding several rules, which enhance the test for the presence of fire. However, this approach does not eliminate fully the problems indicated above, considering the pixels individually, rather than the entire segment and ignores ratio of color components.

In [6] YUV color model for the representation of video data is used. They used time derivative of luminance component Y to declare the candidate fire pixels, then depending on chrominance components U and V classified the candidate pixels into fire and non-fire sections. They report that their algorithm detects less than one false alarm per week. However, this method makes a lot of computations and not good for on the fly decision making.

This article proposes an approach, based on RGB image full segmentation and simplification. As mentioned above, areas of three types are analyzed: containing fire, containing smoke and areas without smoke and/or fire (see examples in Fig 1).

Fig.1. Images with fire, with smoke and without fire and/or smoke.

An important feature of the approach is the preprocessing of the image data, which reduces the affects of nonhomogeneity of light brightness. Further information processing occurs in two stages: training and testing. At the stage of learning a lot of images are analyzed, which contain or not contain regions with fire and/or smoke; then complete image segmentation and simplification are made. The color components of average intensities of segments are registered for further processing. After the formation of data sets the statistical analysis is performed to determine the numerical characteristics of the data. During the testing phase the intensity values, obtained during the training phase are used for the classification by the method of “etalons”. The corresponding algorithms are described in Section 3 of the article.

3. DATA FORMATION

Set of selected images. Sufficient number of images was selected, where visually it is possible clearly to find in each image the areas, containing the fire, smoke or areas without containing fire or smoke. These images are divided into three classes: Class 1, Class 2 and Class 3. In Fig. 1 typical examples of members of all three classes are shown. In the internet, in the technical and scientific literature and in other sources one can easily find a lot of images which satisfy the specified three classes.

Formation of experimental data is performed by extracting numerical information from relevant areas of the image for subsequent statistical processing. To do this, firstly the complete segmentation and simplification of each selected image is performed. Then the values of the color components of the images of three classes are registered. Here is a brief description of the mentioned procedures.

1. Segmentation and simplification of images are produced using the segmentation algorithm, described in [7-8]. Let's first for simplicity consider an image of format Gray Scale (8 bit). In accordance with mentioned algorithm, the entire image is partitioned into non overlapping set of connected areas, each of which is composed of pixels, whose intensities belong to the same range, given by a certain set of thresholds. After rendering of the overall picture segmentation, the operation which is called simplification is performed, during which the intensity of each pixel is replaced with the average value of the segment. During the visual analysis of the segmentation result the simplification operation allows evaluating and comparing different solutions by changing amount and values of thresholds.

For color image segmentation the analogous algorithm described above is used, wherein the image first is decomposed into the color components. Then for each component the procedures of full segmentation and simplification are performed, after which the resulting simplified components are again converted into a color image.

It is important to select proper amount and values of thresholds for every color component for a good segmentation. The results of preprocessing of the test images showed that it is often possible to choose the number of thresholds no more than two. By increasing this number the image area with the fire is divided into many small pieces, which complicates the analysis and interpretation of results. If limited to one or two threshold values, then in most real cases quite adequate color palette turns out, which allows to detect areas with fire confident enough. Selection of threshold values can be performed either experimentally or by using the Otsu algorithm [9]. Fig.2 illustrates the examples of segmentation of an image with one or two thresholds, dividing the interval of the intensities of pixels (0, 255) into approximately equal parts.

2. RGB values of the color components of the corresponding areas are calculated as it follows. By visual analysis of the image area from the class of fire, segments forming a flame or fire are selected, and the mean intensity of RGB components is calculated. Similarly, the average values for the second and third classes of image areas are calculated. The found numeric data is entered into the table.

a

b

Fig.2 Image segmentation and simplification with one (a) or two (b) thresholds.

We denote the initial values of the color components through r_i, g_i, b_i, i=1, 2,…,K, where K is the total number of found segments. Preliminary analysis and numeric data processing, described above revealed some dependence between the intensities of the pixels and the overall brightness of the scene. Therefore it is reasonable to transform the color components by the formulas as follows.

$$R_i = 255 * \frac{r_i}{\sqrt{r_i^2 + g_i^2 + b_i^2}},$$

$$G_i = 255 * \frac{g_i}{\sqrt{r_i^2 + g_i^2 + b_i^2}};$$

$$B_i = 255 * \frac{b_i}{\sqrt{r_i^2 + g_i^2 + b_i^2}}.$$

These formulas just calculate the overall weight of color components of the fixed pixel. For further calculations we use R_i, G_i, B_i normalized components, which eliminate the factor of frame brightness, instead of the original r_i, g_i, b_i ones.

Efficacy of rationing under this scheme is illustrated by Fig. 3, where for comparison the scatter plots of data before and after normalization are shown. It can be seen that in the case of (b), where we use R_i , G_i, B_i, data is grouped more compactly than in the case (a) with r_i, g_i, b_i values. This means that the standard deviation of R_i, G_i, B_i components is less than in the case of r_i, g_i, b_i, which makes them better for revealing some visual characteristics of fire/smoke segments via statistical analysis.

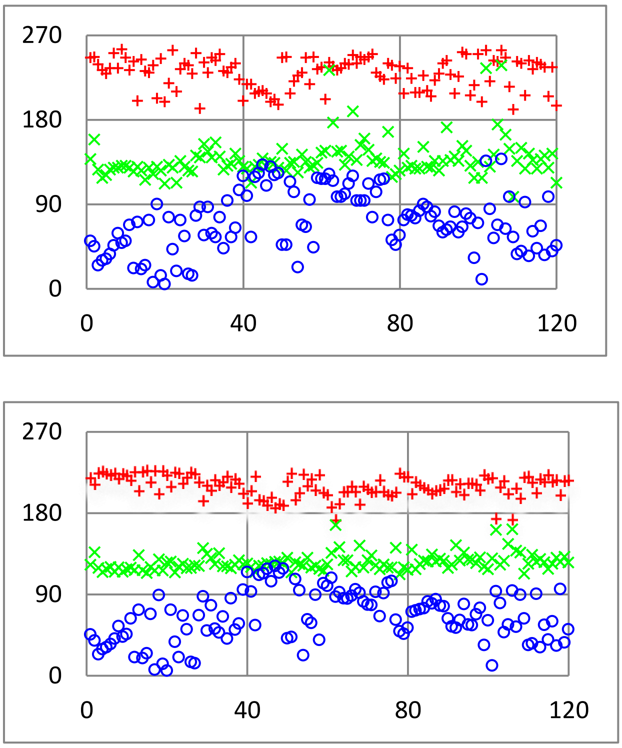

Fig.3 Scatter plots chrominance component data before and after normalization

4. CLLASSIFICATION PROCEDURE

Once image classes with areas whether or not containing the fire/smoke are formed and numerical arrays of relevant data are obtained statistical processing and analysis in order to find the "standard" values of the color components of each class. The classification of the certain image to one of the specified classes can be performed by comparing the values of its color components with reference value (i.e. establishing the presence or absence of the fire / smoke in the image).

To test the effectiveness of the proposed numerical procedures of fire / smoke detecting, each of our classes is divided into two subclasses: A (teaching) and B (testing), applying the random selection. Let's denote by (A1, B1) subclasses which contain only fire, (A2, B2) which contain only smoke, and (A3, B3), which contain only forest patterns. This separation allows us to calculate the number of classification errors and thus to assess the overall quality of the proposed procedure. Table 1 shows the average values and standard deviations of color components for all enrolled subclasses defined above. Accordingly, we will accept the average values of the components given in Table 1 as etalons.

These data indicate that the ratio of levels of color components is different in the classes, and the numerical values correspond to the literature data presented in the introduction.

The classification is done by comparing the color components of the image from the test subclasses, with reference values given in Table. 1. The testing results are as follows: the presence of a fire is detected in 92.5% of cases, but 5.5% of the forest patterns was erroneously accepted as a fire area. In the case of smoke results are slightly worse: 80% of the smoke is detected correctly and a false alarm occurs in 30% of cases. However, through additional processing false alarm rate can be significantly reduced if the inequalities are performed as follows

$$|R - G| < T, \ |R - B| < T \text{ and } |B - G| < T,$$

where T is determined experimentally from the interval [15, 25]. Then the false alarm rate is reduced from 30% to 12%. A similar operation is used in [5].

Thus, the proposed vision-based method of detecting fire and smoke based on the analysis of the color components of different image areas, allows you to take confident decisions during the monitoring of forest areas.

		R	G	B
A1	Mean	209.6	125.6	65.4
	St. Dev.	12.1	9.4	28.2
A2	Mean	143.8	149.0	147.9
	St. Dev.	11.3	2.7	11.6
A3	Mean	161.6	149.1	121.3
	St. Dev.	21.0	14.3	27.1

Table 1. Numerical characteristics of the color components of the training subclasses.

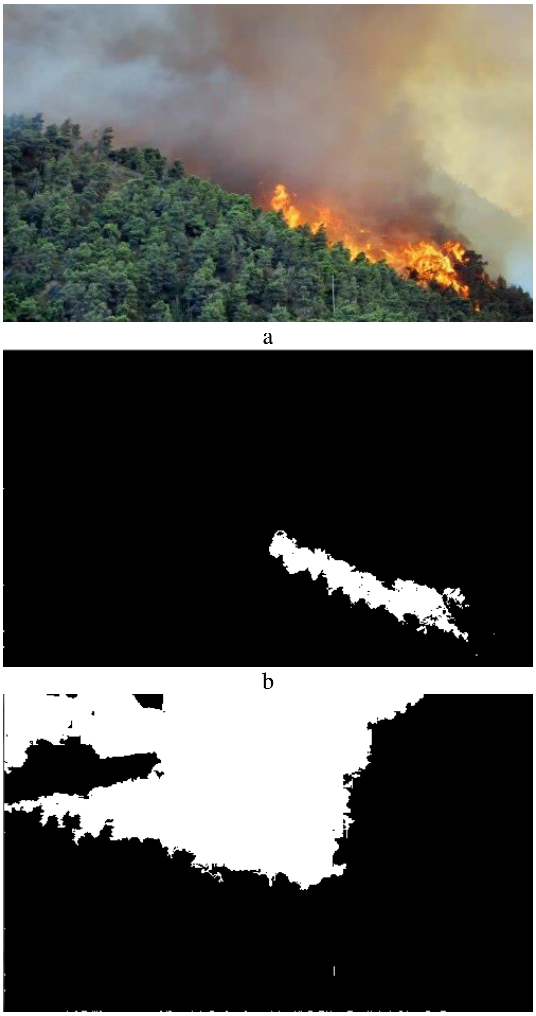

Fig. 4. The original image (a), section with fire (b) and section with smoke (c).

Fig. 4 shows examples of the detected areas with fire (b) and smoke (c) in the image (a).

5. CONCLUSION

We propose a method for the detection of fire and smoke through the usage of photographed data of controlled area followed by computer processing of the data. A method for reading information, preprocessing of an image color components, the statistical processing and data classification is proposed. The method is working very fast and can be used for online calculations and decision making. The efficiency of the proposed procedures is shown: 92.5% detection ration and 5.5% false detection alarm. The proposed method can be used in the monitoring systems of the area to detect fire and smoke. The proposed procedures can be successfully applied to fire and smoke detection problem from a video stream taken by using UAV.

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