Forest Fires Detection in Digital Images Based on Color Features

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Abstract: One of the biggest ecological catastrophes are forest fires. Early detections of the fires can have significant impact on the control of forest fires which is very important for successful extinguishing. Areal or satellite surveillance is one of the systems used for monitoring forest areas. Based on the images provided by this system, fire can be detected by using some image processing techniques. In this paper we proposed an algorithm for forest fires detection based on color features. Different characteristics of the color components of YCbCr color model were used to detect fire based on the predefined threshold values and combination of the components values. After pixel classification morphological operations were performed to remove incorrect classified pixels. Our proposed method successfully detected fire regions in forest images with different lightning conditions.

Key–Words: Image processing, YCbCr, fire detection, color features

1 Introduction

Forest fires are one of the big ecological catastrophes. Every year thousands of people die as result of forest fire. Enormous material damages are made and immeasurable impact on ecosystems is made. There are predictions that forest fires (natural and intentional fire clearings) will burn around half of the all forests in the world by year 2030. In Europe alone, around 10.000km^2 of forests is burnt every year. Estimates are that over 20% of carbon-monoxide emissions in the whole world is made as result of forest fires. That fact combined with global warming is making forest fires a serious problem that needs to be tackled on large scale.

Suppression of already active forest fires is not a subject of this paper and area of research. Here, we will research methods for detections of forest fires. This is important area that can make big impact on control of forest fires due to fact that most forest fires are detected when they are already spread significantly. Currently there are several classes of fire detection systems that are in use worldwide. Some of the those systems used are:

- Human based detection systems. These are constituted, usually, from watch towers and on foot or vehicles patrols, where humans visually search for forest fires.
- Sensor networks constitutes of wireless sensors spread over large areas that detect changes in temperature or some other parameter that can indicate that forest fire has started.
- Areal or satellite surveillance. These systems can with relative ease cover huge areas of forest but there is limitation. Low quality of images mean that only bigger fires can be detected. Also atmospheric conditions can limit this method greatly.

Image processing can introduce new techniques for forest fire detection. Today digital cameras are very cheap and can be connected directly to the computer and captured images can be processed in real time. Using some sort of detection algorithm can automate and speed up traditional fire detection systems.

For example, forest services can place hundreds or thousands of wireless digital cameras throughout area they monitor and connect those cameras to central computer in base that will process live feed and raise alarm if fire is detected on some of the camera feeds without need for human supervision.

In this paper we proposed an algorithm for automatic fire detection in digital images based on color features in YC_bC_r model. Based on characteristics of the fire regions five rules for pixel classification were proposed. All rules are binary, pixel either satisfies the rule or not. Pixels that satisfy all rules are classified as fire pixels and vice versa, if pixel fails to satisfy at least one rule it is not classified as fire pixel.

The remainder of this paper is organized as follows. Literature review is given in Section 2. Section 3 describes our proposed algorithm while in Section 4 experimental results were presented. At the end in Section 5 conclusion and possible future work were given.

2 Literature review

Forest fire detection is active research topic. Usually techniques for automatic fire detection include some image processing since the information are collected as satellite images, unmanned aerial vehicle image data, images from cameras set into the forest, etc. Other techniques are based on analyzing the data collected from wireless sensors networks [1], [2].

Authors in [3] proposed an approach for forest fire detection using a rule based color model for fire pixel classification. This method is using RGB and YC_bC_r color models. They established seven rules for fire pixel recognition. Efficiency of the algorithm was tested on images which contain fire or fire-like regions. The percentage of false alarm is very low and the algorithm is cheap in computation so it can be used in real life.

In [4] support vector machine (SVM) trained with static features of the fire extracted from Gaussian mixture model was used. Fire was detected with good success but still had a problem with false positives when red objects are on the analyzed image.

An algorithm based on pixel color and textures analysis was proposed in [5]. The proposed algorithm improved detection accuracy and reduced false positives in comparison with pixel color only methods and less parameters were used compared to the similar algorithms from the literature.

Color based method for forest fire detection was proposed in [6]. The proposed method was made for forest fire detection in video sequences. It was based on $CIEL*a*b*$ color model and motion detection. Reported results were comparable to the other state-of-the-art.

In [7] an algorithm based on edge detection was proposed. Two stage algorithm for fire and flame edge detection was proposed. In the first stage the coarse and superfluous edges were detected and then the fine edges of the flame and the fire were recognized while the irrelevant artifacts were removed. Experimental results proved that the proposed algorithm was effective and robust.

A method based on spatial data and artificial neural networks was proposed in [8]. Digital images of the forest were converted from RGB to XYZ color space and the fire regions were detected by anisotropic diffusion. Radial basis function neural network was trained with the color space values of the detected fire regions. Trained model was tested on publicly available forest fire dataset and it was reported that the proposed algorithm was effectively detected forest fires.

3 Our proposed algorithm

In this paper we proposed a method for fire detection in digital images based on the color features. In order to identify if a pixel is fire or not several rules have been established and in order to classify pixel as fire all rules need to be satisfied.

In this paper an algorithm for fire detection based on components of YC_bYC_r color space was proposed. In YC_bYC_r model, Y represents the luminance component while C_b and C_r describe the chrominance factors. Component Y is the brightness or $luma$, C_b is defined as difference between blue and brightness and C_r is difference between red and brightness. This color model was used in various applications such as skin detection [9], JPEG compression [10], medical image segmentation [11], hand gesture recognition [12], etc.

In this paper different characteristics of fire pixels were recognized and defined. Based on some statistics of fire and non-fire regions we will determine the five different rules for pixel classification.

The first two rules were deduced from observing average values of Y, C_r and C_b values on images from data set. First the image was converted from standard RGB color system to YC_bC_r color system by the following equations:

$$\begin{aligned} Y &= 0.299*R + 0.587*G + 0.114*B \\ C_b &= -0.168*R - 0.331*G + 0.500*B \\ C_r &= 0.500*R - 0.418*G - 0.081*B \end{aligned} \quad (1)$$

By calculating the average values in manually selected fire and non-fire regions for all components it was concluded that Y and C_r components are higher then C_b in fire regions while it is not always a case for non-fire regions. The first two criteria for determining fire pixels were defined by the following equations:

$$R_1(x,y) = \begin{cases} 1, & \text{if } \; Y(x,y) \geq C_b(x,y) \\ 0, & otherwise \end{cases} \quad (2)$$

and

$$R_2(x,y) = \begin{cases} 1, & \text{if } \; C_r(x,y) \geq C_b(x,y) \\ 0, & otherwise \end{cases} \quad (3)$$

where $Y(x,y)$,$C_b(x,y)$ and $C_r(x,y)$ are Y, C_b and C_r component of the pixel (x,y) respectively.

The next rule is based on the fact that fire regions in image are always brighter than the rest of the image. Therefore we can conclude that it is necessary that all color components (Y, C_b, C_r) must have greater values in fire regions than the average value of entire image. This rule can be define by the following equation:

$$R_3(x,y) = \begin{cases} 1, & \text{if } \; Y(x,y) \geq Y_{mean} \wedge \\ & \quad C_b(x,y) \leq, Cb_{mean} \wedge \\ & \quad C_r(x,y) \geq, Cr_{mean}, \\ 0, & otherwise \end{cases} \quad (4)$$

where Y_{mean}, Cb_{mean} and Cr_{mean} represent the average values of the each component in the image.

The following rule was determined by looking one color channel of the image at the time. Fire regions in the images have C_b component in low intensities and at the same time C_r component have high intensity. Based on this observation, the following rule can be defined:

$$R_4(x,y) = \begin{cases} 1, & \text{if } \; |C_b(x,y) - C_r(x,y)| \geq Th \\ 0, & otherwise \end{cases} \quad (5)$$

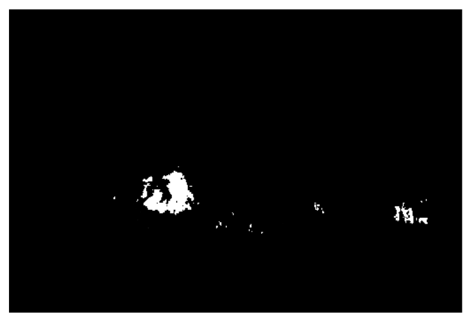
where Th is empirically determined threshold value. By experimentally comparing percentage of detection and false positives we established that optimal value for threshold is 70.

The last rule that we will use in this paper also takes in consideration only C_b and C_r component since Y component can vary from lighting conditions. By manual selection of fire regions on multiple images and determining thresholds we established the last rule defined by the following equation:

$$R_5(x,y) = \begin{cases} 1, & \text{if } \; C_b(x,y) \leq 100 \wedge \\ & \quad C_r(x,y) \geq 150 \\ 0, & otherwise \end{cases} \quad (6)$$

Each pixel in the image that fulfill all stated rules was considered as fire pixel. After pixel classification, we additionally applied morphological operations in order to remove isolated pixels. After applying these five rules, some individual pixels might be recognized and they were treated as a noise, thus morphological operation of opening and closing was done to remove it.

(a)



(b)

Figure 1: Results of our proposed algorithm: (a), original image (b) detected fire regions by our proposed algorithm

4 Experimental results

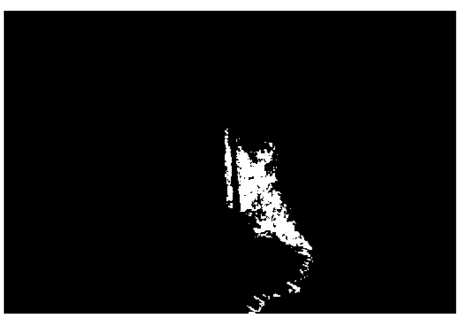
Our proposed method was implemented in Matlab 2016a. All experiments were performed on the platform with Intel ® Core^{TM} i7-3770K CPU at 4GHz, 8GB RAM, Windows 10 Professional OS.

For testing our proposed algorithm we used images from public data set available at https://www.forestryimages.org. We tested our proposed algorithm for 100 different images with forest fire. All images have size 768×512.

Pixels that were categorized by our proposed algorithm as fire pixels are white and non-fire pixels are represented by black pixels in the following examples.

Fig.1 shows example of fire detection by our proposed algorithm. In original image fireman with similar color features as the fire is presented. As it can be seen our proposed algorithm successfully recognized fire and did not falsely recognized fireman. In Fig. 2 results of our proposed algorithm for image with different lightning condition was shown. As it can be seen, fire regions were correctly recognized for this image also. The last example shows the fire region recognition in images where some of the trees have similar features as a fire. Our proposed algorithm correctly recognized fire regions.

(a)



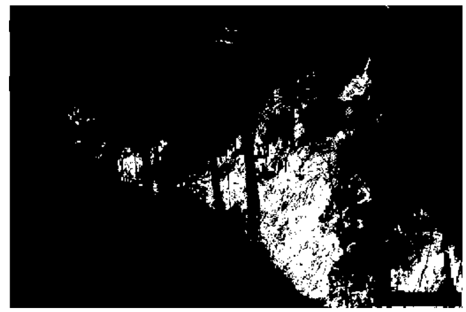
(b)

Figure 2: Results of our proposed algorithm: (a), original image (b) detected fire regions by our proposed algorithm

5 Conclusion

In this paper we proposed an algorithm for early fire detection based on color features. Images were transformed to YC_bC_r model and five different characteristics of the fire in that color space were defined and used for pixel classification. Experimental results shown that our proposed method successfully recognizes fire region in the forest images. In future work, our proposed method can be adjusted for fire detection in other environment where some additional rules must be defined since some objects can have similar characteristics as fire.

(a)



(b)

Figure 3: Results of our proposed algorithm: (a), original image (b) detected fire regions by our proposed algorithm

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