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AN IMAGE SEGMENTATION APPROACH OF FOREST FIRE AREA BASED ON AERIAL IMAGE

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ABSTRACT

In order to determine the forest fire danger rating quickly while finding it during the aviation of forest protection, it is important to calculate the fire area. Until recently the area has been mostly calculated by people's experience. With the mature of digital image processing technology, an assumption based on the forest fire area calculation of aerial images has been made, and the key point is how to identify and extract the fire area. In this paper, a extraction method on forest fire area based on the combination of color and gray level information has been proposed. First, the adaptive threshold should be found by applying the Otsu threshold method to a gray image. Then, the image analysis should be made by the RGB space component's characteristics of the target images' color features. Compared with traditional image segmentation methods, experiments show that the proposed method has low false points rate, good area consistency, accurate and clear edge, and can be used to extract and segment the fire area of aerial images.
Keywords: *Forest Fire, Aerial Image, Image Segmentation, Fire Area Extraction*

1. INTRODUCTION

Forest is a precious resource for human existence and development of sustainability. Due to the influence of human factors and natural disasters, forests have been exposed to fire destruction, which badly damages the forest eco-system and threatens the security of human life and property. Forest fire is considered to be one of the most destructive natural disasters affecting the development of society, environment and economy widely. Therefore, forest fire prevention is an arduous long-term task. In the southwest forest zones of China, aerial forest fire protection which brings much convenience to forest rangers is widely used. The application of 3S technology improves the quantity as well as quality of information of air patrol. However, it fails to identify the size of fire area once the accident is detected. In recent years, under the condition of high technology, air detection which promotes thorough study of aerial photo interpretation technology has been widely used. Traditionally it has been featured by manual identification. With constant development of computer technology, it's possible to make the firemen achieve the interpretation and identification of the fire targets by using the computer system. In general, the method of defining the fire area is realized by using hand-held GPS. As to the forest, the fire is unpredictable and usually occur in the fields that it is difficult to walk through. Therefore, helicopters are often used to measure the fire areas. However, this method fails to measure the area of fire timely and cause a lag in terms of arranging work to combat forest fire. It brings a lot of inconvenience to the preparatory work.

At present there is no access to a forest fire area measurement based on aerial images. In recent years, scientists did a lot of researches in the areas of aerial image segmentation. Merino Luis et al developed a system for forest fire monitoring using aerial images. The system uses the images taken from a helicopter, the GPS position of the helicopter, and information from a Geographic Information System (GIS) to locate the fire and to estimate in real-time their properties [1]. Robertson Neil M. et al presented a technique for image segmentation that based on color (the L*a*b* color space is used), texture (using entropy) and image features (gradients) and used for classification of natural land surfaces and man-made structures [2]. Dubuisson-Jolly put forward a new algorithm for combining color and texture information for the segmentation of color images. The algorithm which uses maximum likelihood classification combined with a certainty based fusion criterion is currently being designed to assist an operator in updating an old map of an area using aerial images [3]. Chen, Yan-He et al proposed a genetic algorithm-based clustering approach for aerial image segmentation, which can automatically determine the proper number of clusters and cluster the data according to the cluster validity index [4]. Li Yingchun et al presented a self-adaptive cluster segmentation method for the problem of automatically detecting

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the aircraft location from complex aerial images [5]. Based on the analysis of a large number of forest fire aerial images and the survey from the aviation forest rangers, it's barely seen the crown fire in aerial images during a forest fire disaster and the fog which is released from the burning vegetation changes into white, so the fog area can be generally considered as the actual forest fire area. Dengyi Zhang et al proposed a novel method to detect fire and smoke in two steps and obtain areas of fire and smoke together with the help of Otsu method [6]. Wang Xiaoli et al put forward a segmentation method of smoke in forest-fire image based on FBM and Region Growing [7]. Wang Xiaoli et al presented an automatic statistical segmentation algorithm using a fuzzy segmentation algorithm to map fire extent, active fire front, hot burn scar, and smoke regions based on a statistical model [8]. Zhao Jianhui et al proposed a new color-based method for forest fire segmentation from video image. This segmentation uses two kinds of color features including intensity value and color distribution based on V value of HSV color model [9]. Based on an optimized k-means clustering in the Cb-channel of YCbCr color space and on distribution properties of fire pixels in the RGB color space, a new method was proposed by Rudz Steve et al [10]. Cui Bao-Xia et al put forward a new flame image segmentation method utilizing the distribution feature of the flame image as well as the complementarity between the color information and characteristic in different color spaces [11]. At present, the image processing technology for forest fire images has been using widespread in video monitoring. According to the author's demand, these kinds of algorithm were too complex and time-consuming. It has some difficulties in achieving the segmentation and recognition of the single image.

In conclusion, due to the restriction of natural condition, such as steep topography, poor sighting condition and larger fire area, it is difficult to measure the forest fire's dimension rapidly in the real measurement of forest fire area. So on this front, coupled with the technology of digital image processing, a calculation method of forest fire area based on the aerial image comes out. The specific practices include the following two steps. Firstly, the target area should be identified in the photograph accurately. Secondly, the real area of the target area should be calculated. So how to extract the target accurately is the key to detecting the forest fire area. This paper focuses on the first step of the algorithm to improve a segmentation method for forest fire areas in the aerial image.

2. IMAGE ACQUISITION

The acquisition system of forest fires aerial image is composed of three parts, helicopter, digital camera and computer. Helicopter's Model: AS350 B3 (Made by Eurocopter). Engine: ARRIELIDI. Maximum Range: 666(km). Maximum Cruise Speed: 287(km/h). Standard Cruising Speed: 248(km/h). Hovering Height: 3500-4000(meters). Digital Camera's Model: NIKON D3X. Original Size: 6048×4032 (in pixels). Computer's CPU: Intel (r) Core (TM) 2 Duo CPU 2.53GHz (dual-core). Video card: NVIDIA GeForce 9300 GE.

The photographs used in this paper were shot on a helicopter in the air from March 25, 2012 to April 10, 2012 when a forest fire happened in Dali and Kunming in China's Yunnan province. The size of collected images is too large to process, so we need to carry out image lossless compression. The size should be reduced to 600×400 (pixels), so that the operational time is saved. In total more than 200 aerial images of the forest fire had been acquired. A few pictures which are bright, contrasted well, shot by good viewing angle were selected for experimental analysis.

3. ALGORITHM INTRODUCTION

3.1 Forest Fire Area Extraction Based On Color Characteristic

Through the analysis of more than 200 images from the acquisition on the spot of the forest protection station in the southwest field and the experience of aviation fire man, it's known that the features of the forest fire images which were taken by the plane were smoky and had a low visibility. Generally speaking, the forest fire was barely caused by crown flame but by the ground fire. Almost all the fire area which could be seen in the images was covered by smoke. The fire-head and fire-wire had visual flame, and the fire-wire place and green space could be distinguished obviously. So the aviation firemen defined that the area which was covered by smoke was the area of a forest fire in the early period. Besides, it didn't need to be very accurate when they estimated the scope of the fire area, they just wanted the estimation could be done quickly, roughly accurate, and convenient for the firemen to do strategic deployment and estimated the forest fire rating.

Color is one of the characteristics of smoke images. The smoke usually displays several specific colors in aerial images. The smoke area can be extracted from the images through the specific color detection [15-16]. In natural light irradiation, fire smoke appears white, black and gray. In RGB space,

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the value of R, G and B components in these colors is basically equal. According to the difference of comburant, combustion temperature and illumination condition, the color of the smoke appears different brightness. Therefore, due to the value of R, G, B three components of the target area are relatively close, but are not in the area of land, trees, etc., this paper presents a kind of segmentation based on RGB similarity which is used for forest fire aerial image extraction. The following formula (1) is used to calculate variance and classify the area:

$$\begin{cases} \overline{x} = \dfrac{R+G+B}{3} \\ \sigma^2 = \dfrac{(R-\overline{x})^2 + (G-\overline{x})^2 + (B-\overline{x})^2}{3} \end{cases} \quad (1)$$

Where R, G and B are the value of three color components respectively. $\overline{x}$ is the mean value of three color components. σ^2 is the variance of three color components.

3.2 Algorithm Steps

According to the characteristics of aerial images of forest fires, the proposed algorithm steps are as follows:

Step 1: Compress the collected image. Reduce the size to 600 × 400 (pixels).

Step 2: Through enhancing image, the image A_0 can be obtained.

Step 3: Change the enhanced image to gray level. Use Otsu [12, 13] to obtain the adaptive threshold value T .

Step 4: Scan the enhanced color image from the first line to the last line for each pixel. Detect the similarity between the R component value, G component value and B component value of the pixel. Use the following formula (2) [14] to calculate the gray-level t of the pixel. Compared with T (from Step 3), if $t > T$ and the similarity between RGB of the pixel achieve a certain condition, change the image pixel value in the corresponding position to 1, otherwise change it to 0. Then, the binary image A_1 can be obtained.

$$gray = 0.299R + 0.587G + 0.114B \quad (2)$$

Step 5: Use morphological open operation and closed operation to process the binary image with iterative methods, and eliminate the small target in the binary image. Further remove the interference of the image.

4. EXPERIMENTAL ANALYSIS

4.1 Image Enhancement

Histogram equalization is a method of image processing in spatial domain. Specifically, it's used in the processing of pixels, processing model is matrix data, but color image data is a three dimensional array. So it can not directly use histogram equalization method to deal with color image data. According to the characteristics of the RGB color image, we need to equalize the histogram in the each component, and then compose the three equalized component to draw a RGB color image of histogram equalization, as shown in figure 1.

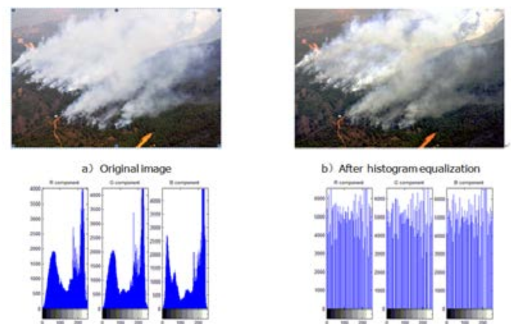

Figure 1: Color Image Histogram Equalization

From the result it is seen that the image contrast is strengthened observably, and the image displays more clearly.

4.2 Image Segmentation

The enhanced image is changed (from figure 1) to gray level. Using Otsu obtains the adaptive threshold value T =110.

And then following processing: Scan the enhanced color image from the first line to the last line for each pixel. Detect the variance $\sigma_{i,j}{}^2$ between the R component value, G component value and B component value of the pixel. Calculate the gray-level $t_{i,j}$ of the pixel. And then use the following formula (3) to obtain the binary image as shown a) in the figure 2.

$$g(i,j) = \begin{cases} 1 & if \quad t_{i,j} > T \cap \sigma_{i,j}{}^2 < 40 \\ 0 & else \end{cases} \quad (3)$$

Eliminate the small target in the binary image as shown b) in the figure 2, and use morphological open operation and closed operation to process the binary image with iterative methods for five times, and eliminate the small target in the binary image again as shown c) in figure 2.

Figure 2: Segmentation Algorithm Results

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4.3 Comparison With Traditional Methods

According to several common thresholding segmentation methods which are used more widely, some comparison experiments have been done. The experimental result was shown in the following figure 3. The purpose of the thresholding segmentation which is as the most fundamental method is to divide image space into some meaningful areas that are corresponding to real scene according to image grayscale. Each area internal grayscale is symmetrical, and grayscale between adjacent areas is different, a boundary is existed there. By simulation experiment with MATLAB, the author obtained and compared four segmentation results that are from threshold segmentation algorithm based on the gradient, threshold segmentation algorithm based on two-dimensional entropy, threshold segmentation algorithm based on concavity analysis and threshold segmentation algorithm based on the moment remains, and found that all these results were not perfect. In adaptive segmentation to forest fire image, traditional thresholding segmentation methods overlook the characteristics of the target area, and do not apply aerial patrol on forest fire. The algorithm in this paper can extract the target fire area completely. And it's helpful for further calculation of forest fire area.

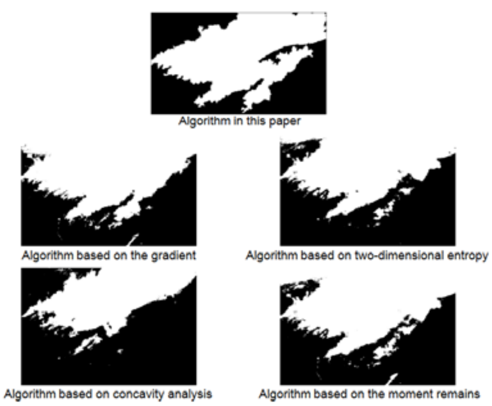

Figure 3: Traditional Methods Comparison Results

4.4 Data Variance Selection

Through the simulation analysis in MATLAB, using three-dimensional image represents the variance of three-channel RGB components, as shown in figure 4. The result b) in figure 4 shows that the corresponding variance value is small in the target area, different from the variance value in background region. In order to facilitate observation of the readers, z axis in figure 4-b) is shown as standard deviation. Based on the analysis of the target area, it is concluded that $\sigma^2 < 40$, while segmentation effect is the best. From practicing in many of the same type of forest fire's aerial images, the result is ideal and viable.

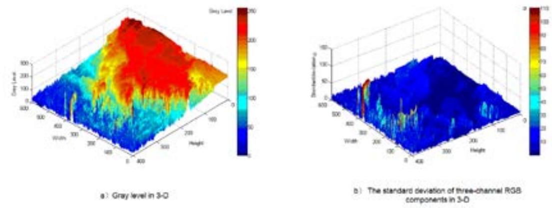

Figure 4: Variance selection displayed in 3-D

5. CONCLUSION

Till now, many segmentation algorithm have been mentioned by referring to various theories, the researches in this area are still under way. Although lots of work has been done in image segmentation area, there is neither general image segmentation algorithm nor successful objective standard of segmentation. Thus, some segmentation is proposed just for specific cases and there is no suitable one for all common image segmentation algorithms. In fact, it's impossible to have a universal algorithm because different images differ in thousands of ways.

Through simulation analysis in MATLAB, the author in this paper proposed an appropriate method of image extraction and segmentation for forest fire's aerial images, and comparing with conventional methods. Experiments show that by this method, the classification error rate is low, area consistent edge is clear, precise, and has good robustness. This method is suitable for extraction of aerial image of forest fire. And it builds a good foundation for area calculation for forest fire. The author will base on this algorithm to further develop the research and design a calculation method for the forest fire real-time area, which is suitable for aerial images.

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