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Research of Forest Fire Smoke Recognition Method Based on Gray Bit Plane Technology

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Abstract

Apply the separation principle of the physical contradictions in TRIZ into the simulation of forest fire smoke and propose a forest fire smoke recognition algorithm based on gray bit-plane(short in FFSGBP) to change the problem of identifying the smoke into the analysis on the bit-plane images. To get eight images of moving smoke, the separation process on smoke moving images is necessary; use high-diagram image (the 7th,the 8th image) to extract contours, and extract the contour of the remaining images in the same position. Superimpose the information extracted, get the smoke model. By adding motion operators to the original image, we could simulate the motion of discrete smoke better, by using mean filter, we could reduce the influence of noise, and it can improve the reliability of the experiments. The results show that compared with the traditional method based on HSI model, the proposed algorithm can achieve the fire smoke detection quickly and obtain the contour model of the smoke inside efficiently and accurately.

Keywords: *TRIZ theory, gray bit plane, contour extraction, mean filtering*

1. Introduction

After images are nearly stably transferred, we can analyze the images' content further to realize the monitoring, alarming and other intelligence operations on forest fire. In the early time of a forest fire, it usually manifests in the form of smoke, so the identification of the smoke is considered to be a good way to judge whether there is a forest fire.

At present, the occurrence of forest fire is mainly monitored by far infrared and visible light in domestic. The smoke recognition algorithm based on least squares support vector machine [1] uses the color characteristics and correlation coefficient as the feature input vectors, it can reduce the input dimension and shorten the training time, which solves the problem of large amount of data it needs effectively. Even though SVM has a good recognition of smoke, but its pattern classifier selection [2] can has high false rate when detecting forest fire smoke; method based on wavelet transform [3] and sparse optical flow increases the ratio of high frequency and low frequency energy, trace motivate area, and get the average offset and phase distribution, which can work as the feature of the smoke. With rapid development of image processing, it becomes possible to use image

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processing technology to monitor the occurrence of forest fire rapidly and effectively. Smoke detection algorithm based on block [4-6] extracts the motion block by frame difference method, through the results of two-dimensional wavelet transform and the motion estimation to judge the occurrence of smoke.

Usually, frame difference and HSI model are selected to recognize forest fire smoke among the above smoke recognition methods. But the former needs to get the multiple images, and once the shake of frame exists, the frame difference method will fail. The latter one can get the result only based on a single picture. But the calculation and conversion between RGB and HIS cost a large amount of time. In this paper, we apply the TRIZ theory into detection, using the method based on gray bit plane and regional adaptive method to detect smoke suspicious area in a single figure with smaller amount of computation.

2. Application of TRIZ to Analyze Smoke Identifying Simulation Problems

Among the smoke recognition algorithms, most of them require complex calculations, to get better result, but at the same time, they consume a lot of time. In actual forest fire monitoring process, in which case when they are really applied, high strict time requirements becomes a big question. Against the problem, we use the theory of physical contradiction separation principle of TRIZ to get a more accurate and essence interpretations of system problem.

Physical contradiction [7] in TRIZ theory is defined as when the engineering parameters for a technical systems has the opposite contradictory demands, namely the parameters need to be improved and the worsening parameters are the same one, the contradiction referred to physical conflict. In contradiction matrix of TRIZ theory, there is no corresponding innovative principle for the intersection of a unified parameter; you need to physically separate the contradictions in order to find corresponding innovative principles. The problem that we currently faced is that we want to secure enough time for the algorithms to calculate and at the same time minimize the computing time to improve efficiency. Interval at this time became a physical contradiction. For monitoring systems, there are two methods that can reduce the computation time and improve the calculation accuracy at the same time, one is proposing an appropriate algorithm, the other is reducing the amount of information the image contained. No matter which method, we need to analyze forest fire smoke image to find a solution.

The theory of physical separation principle of contradiction has four main principles [8] space-based separation, time-based separation, condition-based separation and whole-part-based separation. The relationship between the smoke and the image can be described as the relationship between the whole and the parts, so we take the whole-part based separation principle to analyze the problem.

Whole-part-based separation principle mainly solves the problem by separating the conflicts into different levels, which can reduce the difficulty of the problem. There are 40 innovative principles in physical contradiction separation principle that are closely-related, and 9 of them can be used to solve the contradiction based on whole and parts:

(1) Innovation Principle 12: equal energy;
(2) Innovation Principle 28: replace the mechanical systems;
(3) Innovation Principle 31: porous material;
(4) Innovation Principle 32: color change;
(5) Innovation Principle 35: a physical or chemical parameter change;
(6) Innovation Principle 36: phase transition;
(7) Innovation Principle 38: gradual oxidation;
(8) Innovation Principle 39: in an inert environment;
(9) Innovation Principle 40: composite material.

After analyzing nine innovative principles, only (4) and (5) are related, the principle (4) has 32 innovative principles, including the followings:

(1) Change the color of the object or the environment;

(2) Change the transparency of the object or environment;

(3) Add color into the object to observe objects or processes that are difficult to see;

(4) If you add a color, consider enhancing luminous track or atomic tag;

The principle (5) has 35 innovative principles, including the followings:

(1) Change the physical state of the system;

(2) Change the concentration or density;

(3) Change the flexibility;

(4) Change the temperature or volume.

We can learn from the 8 principles above that we can observe the details of smoke, which is different from the surrounding environment, by changing the transparency of an object or system and the environment. In the image processing, there is a concept called the bit plane image, which can layer the images according to different gray scale values. The next step is to analyze the images by means of bit-planes.

3. Suspicious Forest Fire Smoke Region Detection Method based on Bit Plane Graph

Gray bit plane [9] can obtain gray-scale image by separating the different bit planes that has the gray-scale a binary value, different gray bit plane shows different details, the Figure 1 showed eight gray bit planes.

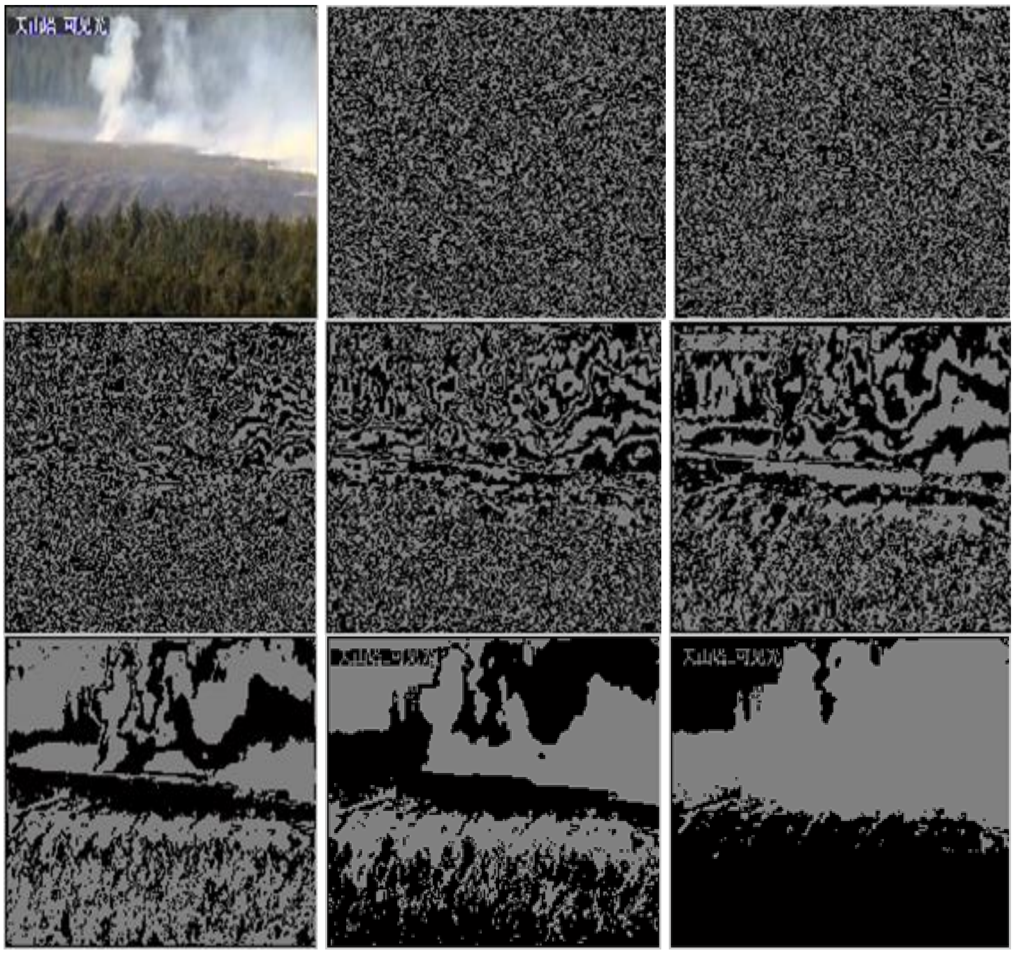


Figure 1. Original Image and Gray-scale Bitmap

After getting the gray bit-plane, we need to extract the information it contains. In order to use the information that high-bit images carries, prior to extract information, we need to weaken [10-12] the low-bit information and smooth the high-bit information on the image.

This paper uses mean filtering [13] to process the gray image.The filter is a method commonly used in image de-noise, which uses the average value of gray values of several pixels in the neighborhood to replace the gray value of the current pixel in order to reduce the sharp changes of gray value, first, set the image function as:

$$Z(i, j) = T(i, j) + x(i, j) \tag{1}$$

In which, $T(i, j)$ is the image information function, $x(i, j)$ is the noise function. Then, use the smooth formula to calculate which can be defined as:

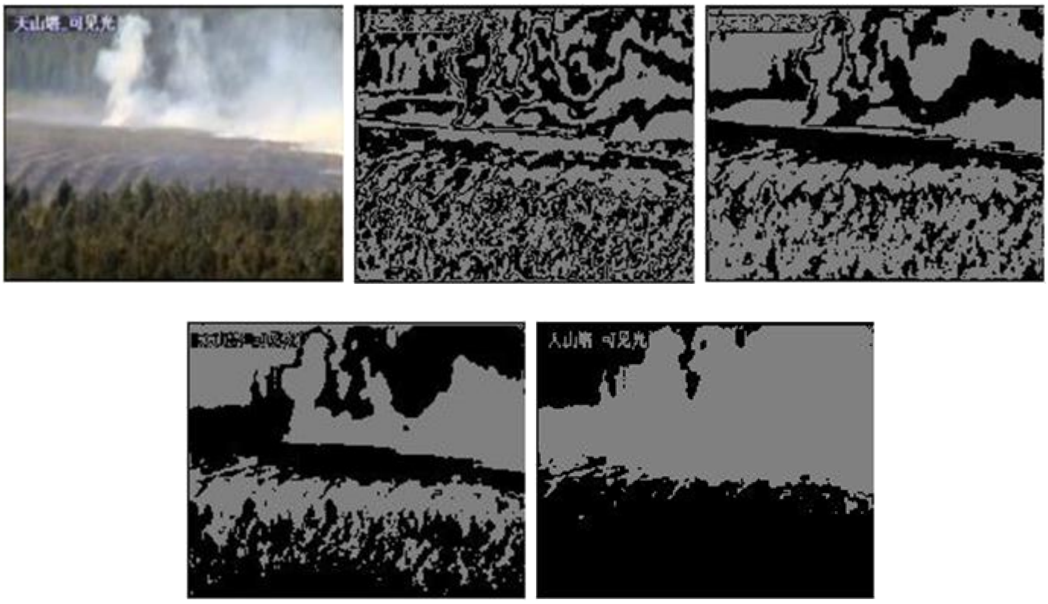
$$\tilde{Z}(i, j) = \frac{1}{N}\sum_{1}^{4} Z(i, j) = \frac{1}{N}(\sum_{1}^{4} T(i, j) + x(i, j)) \tag{2}$$

In which, $N = 4$, according to the analysis of probability and statistics, the noise variance is:

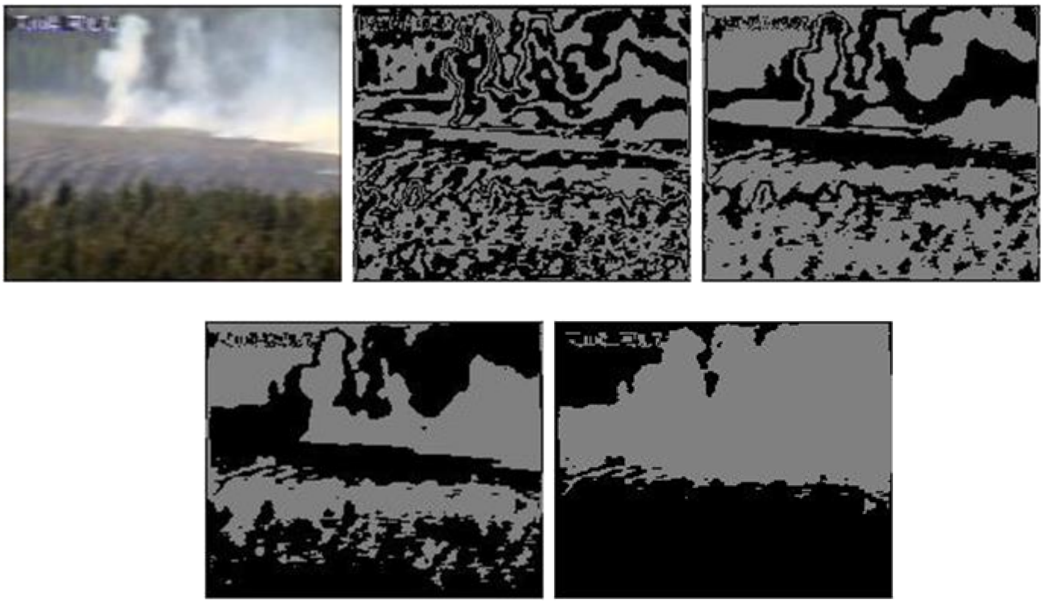
$$D\left(\frac{1}{N}\sum_{1}^{4} x(i, j)\right) = \frac{1}{N^2}\sum_{1}^{4} D(x(i, j)) = \frac{1}{N}\omega^2 \tag{3}$$

In which, D is the variance operation, ω^2 is the noise variance without processing of neighbor smoothing. The noise variance through processing of neighbor smoothing reduces N times in order to achieve the effect of noise reduction and image smoothing. Figure 2A is the bit plane graph after being filtered, it can be seen that information of low level is effectively weakened.

As smoke is discrete and moveable, therefore, introduce the motion blurring operator [14] before filtering in order to simulate smoke better, Figure 2B is the bit plane graph which has added the motion operator and the connectivity of smoke areas is improved.



A. Process of Mean Filtering



B. After Adding Motion Blur Operator

Figure 2. Bit Plan under Different Circumstances

The variance of detail model of an image will reduce N times in the process of de-noising by mean filtering, which is suitable for bit plane with blur details. Combining with the analysis and processing in above, the smoke recognition model proposed in this paper can be defined as:

$$\delta(x,y) = g_{K-2}(x,y) \bullet g_{K-1}(x,y) \quad (4)$$

$$\zeta(x,y) = \sum_{k=4}^{K-1} (g_k(x,y) \bullet \delta(x,y)) \times 2^{K-k} \quad (5)$$

In which, $\delta(x,y)$ is the overall model of smoke, $\zeta(x,y)$ is the detail model of smoke , $K=8$ in this paper. Forest fire smoke model can be quickly calculated by the method.

The main idea of the smoke models is described by the following points:

(1) Add the motion operator original picture;

(2) Get 8 bit-plane images by separating process;

(3) Get the contour of smoke by contrasting the high-bit images (the 7th and 8th);

(4) De-noise the obtained images;

(5) According the extracted contours, extract the information of the remaining images in the same position;

(6) Superimpose information extracted of 8 images;

(7) Get smoke models.

Through the above steps, we can obtain the recognition model of the smoke.

4. Experimental Verification

In order to verify the performance of the algorithm, the experiment is based on 23 video segments, which are obtained from monitoring center of forest. The segments are divided into two categories: visible light image and far-infrared image, each video segment contains a scene of smoke, the wind weather, no wind weather and the fire situation in initial, mid time. The experiment is achieved on Matlab. In Figure 3, it showed when it works in windless environment, because low bit-plane information had been weakened by filter, and it does not contain the overall information of the smoke, so we only list the bit-plane images after the third one.

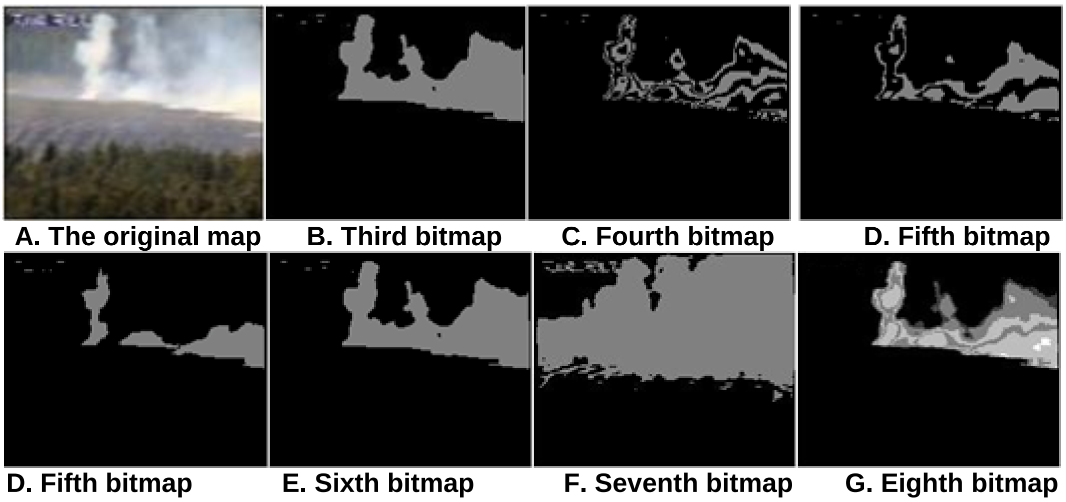


Figure 3. Results of FFSGBP Algorithm

Figure 4 showed the identification result in different situations. They are original image, pre-processing image, post-processing image and the simulation image.

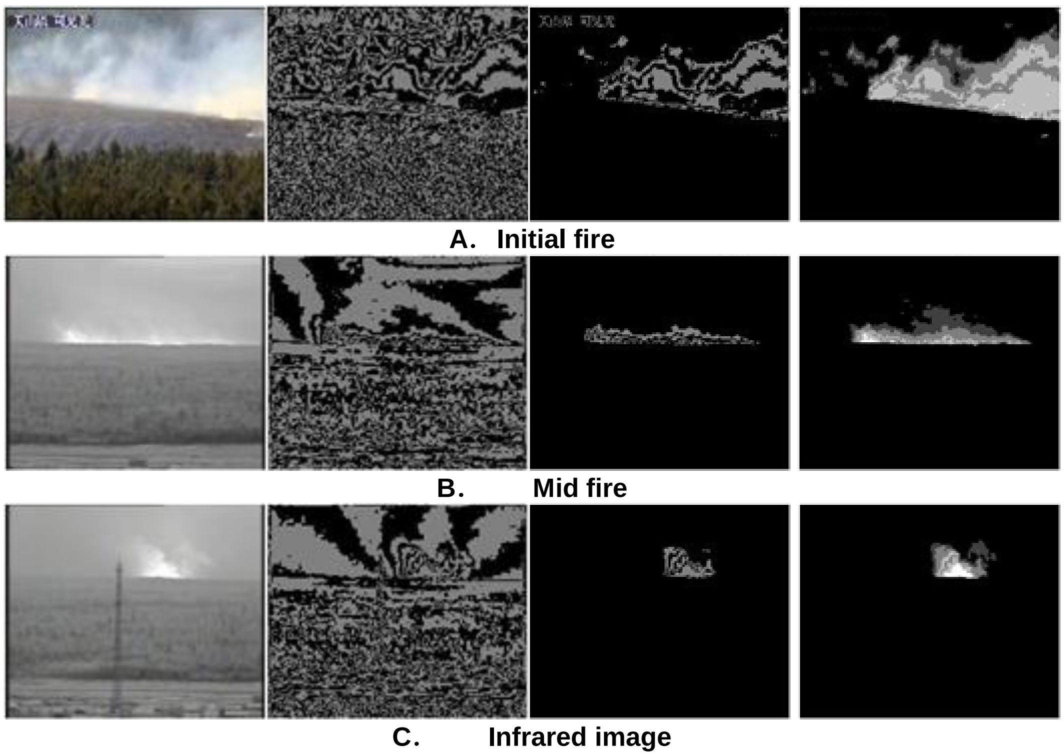


Figure 4. Smoke Recognition Results under Different Circumstances

In order to prove the validity and effectiveness of the method, we made the comparison with the method based on HIS model [15], Figure5 is comparison chart, and we get the average processing time as shown in Table 1. The results can be seen from the comparative experiments, the processing speed of the proposed method is much quicker than approaches based on HIS model, even though the smoke area are both basically identified.

A. Original image **B. Gray-scale image** **C.HSI method** **D. Method proposed**

Figure 5. Comparison with HSI Experimental Diagram

Table 1. Comparison Result of Two Methods

Image type	Fireproof period	Fire	Image number (piece)	HIS (s)	FFSGBP (s)
Visible light	spring	initial fire	280	5.312	3.827
Visible light	spring	mid fire	280	5.287	3.815
Infrared image	autumn	close range	150	2.839	2.035
Infrared image	autumn	outlook	150	2.814	2.012

5. Conclusion

The goal of forest fire smoke recognition is to identify smoke timely and accurately. This paper uses gray bit plane to divide images firstly, and use mean filtering to smooth images and weaken information of low levels in order to guarantee the accuracy of information of high level, and then design the automatic recognition algorithm according to the smoke information reflected by different bit planes. Experimental results show that the method has lower amount of computation and it is able to satisfy the requirement of accuracy and real-time in automatic forest fire smoke recognition.

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