A Method of Forest-Fire Image Recognition Based on AdaBoost-BP Algorithm

Dehong Ding and Sisi Zhu

***Abstract*—**In view of the shortcomings of the existing forest flame recognition technology, in order to further improve and perfect some problems of the flame image recognition technology, provide guidance and technical support for fire detection products. The research is focus on flame information of physical characteristics, which combines with image processing techniques and comes up to a recognition way of forest flame that character of highlight area based on image and a flame recognition method of BP neural network for forest fire based on AdaBoost. AdaBoost-BP method uses the BP neural network as the basic weak classifier, and then updates it through the specific algorithm, and constructs a combination of strong classifier. Those methods are mainly extracting Color, Area and Circularity of pretreatment image, then output AdaBoost-BP neural network learning to realize firework recognition. Using single algorithms and single characteristic to analyze, easily led to accuracy is not high. It not only can make up for that shortcoming but also eliminate interference interruption, and improves efficiency of image recognition for forest.The recognition rate is about 94%, and the training time is about 250 times to achieve convergence. The computation speed is only 0.01292 seconds.

***Keywords*—**image processing, fireworks, recognition, roundness.

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I. INTRODUCTION

Fire, diseases and pests are three kind of natural disasters that can destroy forest. And forest fire is the main disaster of forest destruction, which ranked first[1]. According to statistics, there are hundreds of thousands of forest fires around the world each year, and the affected area reach to several hundred hectares, which account for about 0.1% of the total area of the forest [2]. Forest fire will directly endanger the trees and under story plants, soil and even microbes and the survival of wild animals, simultaneously, to the human life and property and damage of ecological environment. Thus, it's helpful to reduce the loss of forest fire if it can be recognized and alarmed as soon as possible. This forest fire recognition method is proposed on the basis of research on the fireworks general characteristics with the help of computer image processing technology, combined with the features of color, size and roundness of firework. This method ameliorate the defect of simple criteria and poor recognizing accuracy caused by criteria that only analyze sole feature of flame such as color, grain and the growth of flame area. Also, it can eliminate the interference of distractors to some extent and it can improve the recognizing accuracy of forest fire image. Further, it can improve the efficiency of recognition and shorten the time of extracting forest fire flame features by detecting inspecting layers.

Compared with the traditional method of flame detection, using the technology of computer vision to realize automatic fire detection has attracted many scholars at home and abroad, and carried out extensive research for this field.

Krul et al[3] used low-cost digital cameras to detect fires in warehouses of large passenger aircraft. The method is based on the grayscale video sequences, use of pixel intensity on average, standard deviation, second-order moment, the statistical characteristics of combining the humidity and temperature that has nothing to do with the image characteristics of and so on traditional fire detection method in aircraft warehouse fire. The system can be used in parallel with the smoke detector to reduce false positives caused by the smoke detector. In addition, the system also provides visual detection to help flight attendants determine whether or not they are available Fire. However, the system based on the statistical image feature cannot be used as a separate flame detection system.

At present, most studies of flame pixel classification of color video series are based on detection rules. Chen [4] and others uses primitive R, G, B information to develop a series of rules to realize the classification of flame pixels.

Different from Chen, use the color model based on detection rules, Toreyin et al[5] focus on the RGB color model from the flame pixel training set, combined with the use of hybrid gaussian model, achieving good effect in final test. In the recent paper[6], the author use the flame pixel classification method proposed by Chen combined with the motion information detection, and Markov domain to model of the flame flicker process. Marbach et al[7] use YUV color model to represent video data, Y luminance component last time is used to represent the candidate flame pixels, chrominance components of U and V is used to analyze whether the candidate pixels in the fire area. In addition to using brightness and color information, can be also add motion detection to your work. The algorithm they proposed is well controlled by false positives. Unfortunately, they did not mention the number of tested sets. Homg et at[8] using HIS color model roughly extract similar flame area in light and shade environment, then remove the pixels low saturation and low -medium intensity in the obtained region, the aim is to rule out a similar fire area. In addition, they also use a two-valued contour map to determine the size of the flame, and can be labeled as fire, small, medium and senior. They reported the detection rate of 96.94% and gave the false alarm rate and missed rate of the algorithm. However, they did not try to reduce the false alarm rate and the missed rate by changing the threshold value. Celik et al[9] proposed enhance recognition effect to flame pixel using fuzzy logic for general color model. The use of the YCbcr color model to separate luminance information from chromaticity information is more effective than RGB or RGB models. Make the classification more effective that use concepts of the fuzzy logic to replace the existing heuristic approach to distinguish target of the flame and similar flame. However, it is worth noting that the two test sets have not been tested together.

We comes up to a recognition way of forest flame that character of highlight area based on image and a flame recognition method of BP neural network for forest fire based on AdaBoost, it not only can make up for that shortcoming but also eliminate interference interruption, and improves efficiency of image recognition for forest.

II. ANALYSIS OF THE CHARACTERISTICS OF FOREST FIRE FIREWORKS FLAME

There are some obvious visible features in smog and flame of forest fire, such as the color, grain, sparking frequency, area of flame and the change of its shape and so forth. Following are the specific analysis.

A. Features of Color

Forest fire always produces flame and smoke, while the latter usually be different owing to the different comburent. The features of flame color is relatively obvious, which ranges from red to yellow[11]. So forest fire flame with apparent visible characteristic is the basic recognizing criterion[12].

B. Features of Grain

The characteristics of grain vary from object to object, which is the general intrinsic characteristics of objects. Therefore, we can judge whether there is fire or not in accordance with the unique grain of forest fire image.

C. Features of Shape Change

Forest fire is formed over time and its flame has different features in different time, its shape, size and information of edge are change constantly. The change of shape is introduced as follow.

The area of forest fire flame always spread in a continuous and growth tendency. The area of flame can be got via counting the number of bright spot in image.

There is some definite variation regulations in the edge of fire flame. Detecting the image edge is the important foundation of image segmentation and object recognition. Image edge is able to be detected through the rapid change of gray value.

When forest fire occurs, its flame always frequency ranges from 7 to 12 Hz. Flame will spark with a frequency constantly when the forest is burning. The flashing features of flame can be judged from the time-varying regulations of grey value histogram.

The change of forest fireworks form mainly reflects the spatial distribution variation of flame. People can obtain the changes of form by calculating spatial distribution of flame, that is, calculating the relationship of pixels.

Forest burning is a type of diffuse burning, and its flame has obvious layers. Characteristics of layers variation can be identified by observing grey value histogram.

With the burnout of former comburant and the burning of the latter comburant, the position of flame will move constantly[13]. Characteristics of unity movement can always be gained by means of detecting the fringe of image..

III. THE RECOGNITION OF FOREST FIRE FLAME IMAGE

Traditionally, some certain feature is used as the identification of the outbreak of forest fire, which is though timely, not accurate enough. To meet the requirement of promptness and accuracy, this paper gives a way to identify the sign of forest fire, that is, abstracting by layers the color of the fire, its coverage and the roundness of the edge. Under the circumstance when one evidence is not able to identify exactly the outbreak of the forest fire, other ways are to be added to judge whether a fire occurs or not. The specific flow chart is shown in Fig.1.

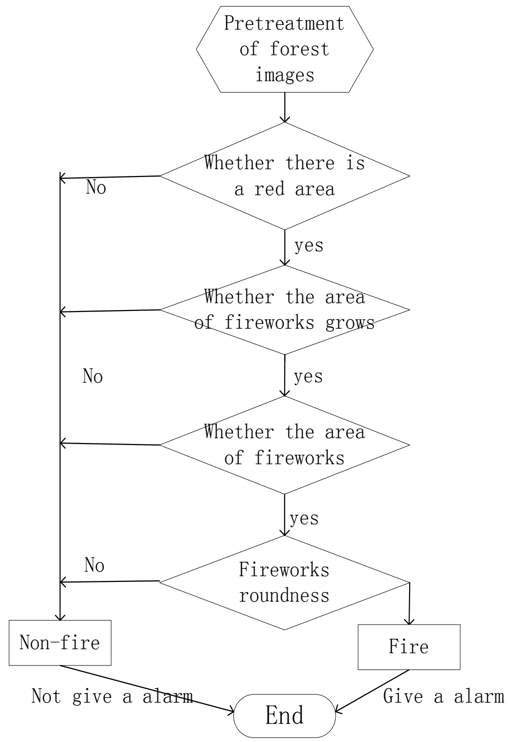

Fig.1. The flowchart of forest fireworks image recognition.

From this figure, one could find that this method first gives a prejudgment to the feature of color, and then to gauge the spread of the firework area, finally, to judge the roundness of edge. It should be laid emphasis on that the following judgment is done in accordance with the former one fitting the image color. When all these three features are met the forest fire can be identified.The alarm system will be trigg ered instantly. Otherwise, it will not betriggered. The method is characterized by its high accuracy and promptn ess.This method to identify her color, size and characteristics of the roundness of the edge is shown as follow.

A. Recognition of Flame Color

The temperature of outer flame is absolutely high. Moreover, its brightness is red indeed so that the color of fire is always characterized by red and consequently, we should prejudge the image firstly. If there is red area in the image, then extract following characteristic; else if not, no other recognition will be extracted. These measures are conducive to improve the recognition efficiency. Algorithm for color recognition is

$$RGBi(x,y) \in [R_1, R_2] \quad (1)$$

In this formula: $RGBi(x, y)$ means the RGB of image pixel to be processed.$[R_1, R_2]$ means the red threshold of fire. Perhaps there is suspected fire in forest when $RGBi(x, y)\in[R_1, R_2]$, then we should enter the following recognition of firework characteristic. When $RGBi(x, y)\notin[R_1, R_2]$, confirming that there is no fire.

Take the case of forest fire image, the paper will tell you a method of color recognition as illustrated in Figure 2.

(a) The original picture (b) Red separation chart

Fig.2. The original image of forest fire and the red componentseparation figure separation figure of forest fire image

Use the instruction as R=RGB(:, :, 1) of MATLAB to separate red component of forest fire image and create an image as illustrated in Figure 2 (b). Secondly, transforming the red component separation figure into the binary image as Figure 3 by thresholding. Finally, judging whether there is red or not according to the existence of brightness in the binary image. If there is bright spot in the binary image then it means red exists in the forest image.

Fig.3. The binary image of red componen

From the Figure 3, we can see that if bright spot exists in binary image then it means there is suspected fire in this image and we should proceed the next recognizing phase.

B. The Spread Recognition of Flame Area

The area of flame can be got via counting the number of bright spot in image. We can use a set of two adjacent frames in image sequence for subtraction to get the increasing area of the forest image flame. Discriminant formula is as follow

$$S(x, y) = S_{i+1}(x, y) - S_i(x, y) \quad (2)$$

In this formula, S_{i+1} (x, y) means the area of red area in the next frame of two adjacent frames; S_{i+1} (x, y) means the area of red area in the previous one. Supposing that the difference value of two frames, namely $S(x, y)$ is zero on the premise that red area appears. It means the area of two frames image is equal, in other words, there is no area growth then the alarm system will not be triggered. If the difference value is greater than zero but smaller than the threshold value then we should judge the area growth of image sequence continuously. If the judged result is the area grow in a sustainable speed then we need judge with the edge roundness further. If the difference value is greater than the threshold value then using the edge roundness to recognize further. It's helpful to reduce the operational time with the help of this way.Take the case of two groups of image sequence, do research on the difference of area growth of high brightness spot when there are fireworks or distractors in image . Fig.4 is four frames sequential image sequence of forest fireworks.

Fig.4. Four frames image sequence of background and suspected fire

As the image sequence illustrated in Fig.4, the high brightness area is gradually expanding with the increment of image sequence. Therefore, perhaps there is suspected fire and a further recognition of edge roundness must be proceed.

Fig.5 is four frames sequential suspected distractors image.

Fig.5. Four frames image sequence of background and distractors of high brightness suspicious area

From Fig.4 we can find out that the high brightness area appears and its area is expanding progressively. On the contrary, the high brightness area in Fig.5 doesn't change nearly. From the contrast of two figures, we can acquire the primary judgment criterion for fireworks recognition, which is on the basis of flame area growth. Transforming the Fig.4 and Fig.5 into binarization image as the Fig.6 and Fig.7 respectively through the thresholding *c* segmentation algorithm. High brightness dynamic change area in the image was circled out.

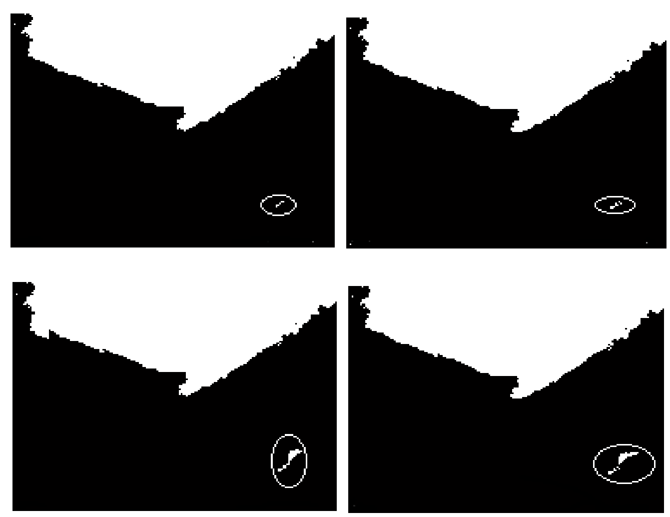

Fig.6. Threshold binarization segmentation result figure of suspected fire

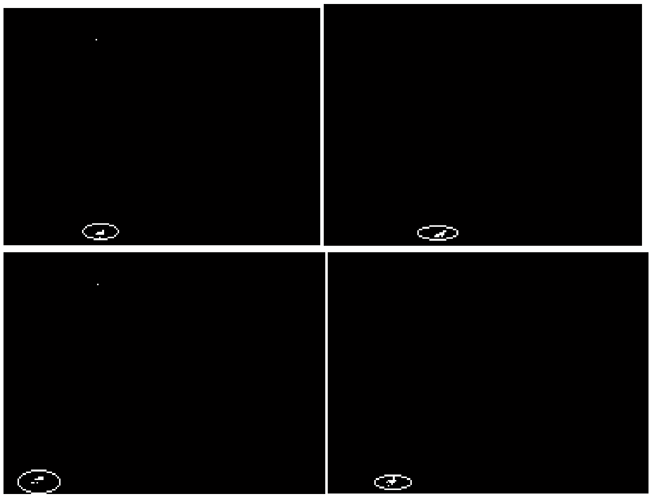

Fig.7. Threshold binarization segmentation result figure of suspected distracto

From the two images we can see more clearly that with the increment of frames in Fig.6 and high brightness area is increasingly expanding, which has the characteristics of fireworks area and we can get the conclusion of suspected fire.

With the increment of frames in Fig.7 and high brightness area doesn't change a lot nearly, which is not in accord with the characteristics of fireworks, that's to say, those are distractors.

C. Recognition of Firework Edge Roundness

Roundness is a concept to describe the complexity of object shape and its formula is

$$\gamma = \frac{L^2}{4\pi S} \quad (3)$$

In this formula, L means the boundary length of object; S means the area of object. From the formula, we can see that the roundness of circular object is 1 and the more complex the shape is, the greater the value of roundness is, namely, roundness is greater than 1. From the formula(3), we can draw a conclusion that in order to recognize the roundness of suspected fire in image, we ought to detect the area of high brightness area and the length of edge.As for area, we extract via counting the number of bright spot in the image after the thresholding enhanced segmentation, which is introduced in the recognition of growth of flame area.It will not be recounted here.As for boundary length, we can extract the edge of segmental object by adopting a Canny algorithm. The diffusivity of fireworks leads to the complication and change of edge, namely the shape of fireworks area is off-circle and its area is expanding continuously. Consequently, we can judge whether there is fire or not in the forest according to the shape and change of high brightness area segmented by consecutive forest image sequence.

As is shown in the picture, the area of high brightness area in Fig.8 is increasing gradually and the edge is complicated and changeable. The shape is off-circle, namely the roundness is greater than 1, it tells that there is fire in the image and the alarm system will be triggered instantly.

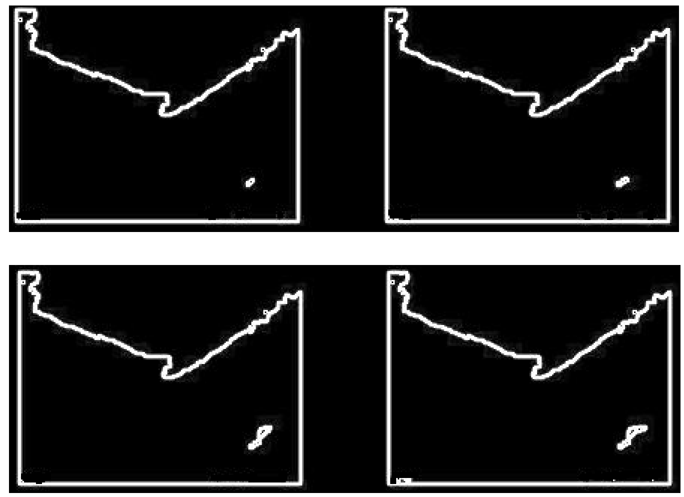

Fig.8. Edge map extracted by canny algorithm

However, the area and edge in Fig.9 fluctuate within a certain range. Namely, roundness doesn't change and it means there is no fire but only distractor then it's unnecessary to alarm.

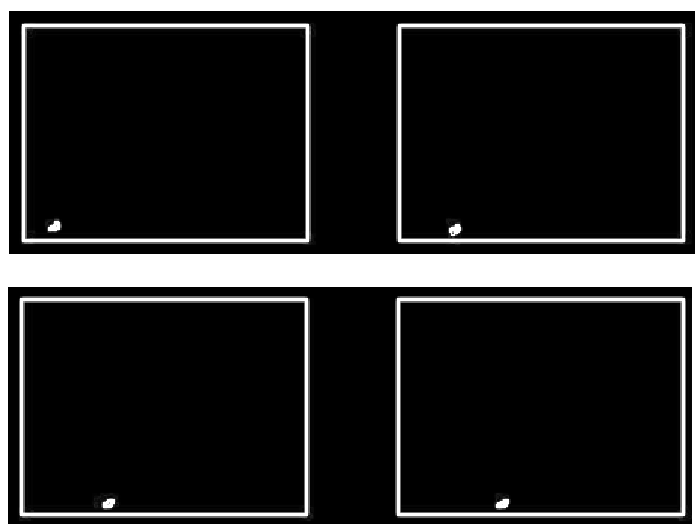

Fig.9. Edge map extracted by canny algorithm

IV. FOREST FIRE IDENTIFICATION BASED ON ADABOOST-BP ALGORITHM

In this paper, base on the method combination of AdaBoot algorithm and BP neural network. we propose the model AdaBoost - BP used to the fire identification system. The AdaBoost-BP method takes BP neural network as the base of the weak classifier, and then upgrades it through the AdaBoost algorithm, and constructs a combined-type strong classifier.

Suppose that the training set is $L = \{(x_i, y_i)\}_{i=1}^{\infty}, x_i \in X, y_i \in Y = \{0,1\}$, the test set is $Q = \{(x_i, y_i)\}_{i=1}^{\infty}, x_i \in X$, and the classification results are expected to be output $y_i = \{0,1\}$. The specific steps of the AdaNoost-BP neural network flame video identification method are as follows.

Step1. Network initialization. The number of positive samples is m_+, the number of negative samples is m_-, and the initial weight of the positive and negative training samples is:

$$D_t(i) = \begin{cases} \frac{1}{m_+} & x_+ \ \textit{for positve sample} \\ \frac{1}{m_-} & x_- \ \textit{for negative sample} \end{cases} \quad (4)$$

The structure of BP neural network is determined according to the dimension of input and output of the sample, and the BP neural network weight and threshold are initialized.

Step2. Prediction of weak predictors. The prediction sequence $g_{t(i)}, i = 1,2,\ldots\ldots m$ was obtained from No. t BP weak predictor neural network trained by the positive and negative sample, and the prediction error and e_i were calculated according to the formula (5).

$$e_i = \sum D_t(i) 1_{[g_t(i) \neq y_i]} \quad (5)$$

Step3. Calculate the weight of the weak predictor a_t

$$a_i = \frac{1}{2} \ln\left(\frac{1-e_i}{e_i}\right) \quad (6)$$

Step4. Update the sample weight. According to the weight a of the weak predictor, the weight of the next training sample is adjusted. The adjustment formula is as follows.

$$D_{t+1}(i) = \frac{D_t(i)}{Z_t} \times \begin{cases} e^{-a_t} & g_t(x_i) = y_i \\ e^{a_t} & g_t(x_i) \neq y_i \end{cases} \quad (7)$$

In the formula, z_t is a normalized factor for the sample weight, and the purpose is to sum the distribution weight to 1 in the case of constant weight ratio.

Step5. Strong prediction function. The weight of the weak predictor a_t is normalized by formula (8)

$$a_t = \frac{a_t}{\sum_{t=1}^{T} a_t} \quad (8)$$

Let $h(x_i)$ is the predicted value for T weak predictor, the prediction result $f(x_i)$ of the strong predictor is

$$f(x_j) = a_t h(x_j), \ j = 1,2,\ldots\ldots \mathrm{n} \quad (9)$$

Step6. Results of the strong classifier. Finally, the prediction results $f(x_j)$ of the strong predictor are classified, and the classification threshold is T_h , and the final identification results are as follows

$$output(x_j) = \begin{cases} 1 & f(x_j) >= T_h \\ 0 & f(x_j) < T_h \end{cases} \quad j = 1,2,\ldots\ldots n \quad (10)$$

Where, output is one for a fire, output to zero means no fire.

V. Result of The Experiment

Take the case of four frames image sequence of Fig.4 and utilize MATLAB, we simulate what is mentioned above such as the operational time of color characteristic recognition, area growth recognition and roundness recognition of edge and gain these data be shown as Table 1.

Table 1 The running time of each recognition algorithm

Recognition of color feature	Recognition of color features	Recognition of area growth	Recognition of edge roundness
The first frame	0.228114s	0.801012s	0.501460s
The second frame	0.223177s	0.690891s	0.501460s
The third frame	0.235136s	0.850059s	0.520893s
The fourth frame	0.222350s	0.740929s	0.531529s

Table 1 is the recognition time of sole characteristic of forest fire image. The method in this paper being proposed is extract by layers the flame color, area and fringe roundness to recognize the fire, which is prejudge the features of image color and then determine the existence of suspected fire. It tells that there is no suspected fire occurs if the red area does not exist, and it's unnecessary to identify other features and the time of color recognition is the operational time of the algorithm. It means it's necessary to further analyze the characteristics of flame area growth if the red area exists. If the high brightness area doesn't change at all, it illustrates there are no suspected fire but only distractors. And the operational time of algorithm is the sum of color recognition time and area growth recognition time. If the flame area increase and the suspected fire appears, we need judge the roundness of image edge. If the roundness of edge doesn't change a lot, it means there are only distractors in image. If the rim is complicated and changeable, the shape is off-circle, namely the roundness is greater than 1, it tells there is fire in the image actually. At this moment, recognition time of forest fire image is sum of color recognition time, area growth recognition time and roundness recognition time. In summary, the forest fire recognition method used in this paper is on the base of multiple features of forest flame, which can eliminate interference of distractors and improve the recognizing accuracy.

When the BP neural network is used for recognition, the training is needed in the early stage. The training samples is divided into training set and test set. The training set is first trained with the training set. Then the test set is used to test the effect. If the accuracy rate is not satisfied, it can be repeatedly trained until the satisfaction. The recognition rate of the algorithm is about 94%, and the training is about 250 times to achieve convergence. The training curve and effect are shown in Figure 10 and table 2.The more samples, the higher accuracy, the preparation and training of samples will take a lot of time. That's a drawback.

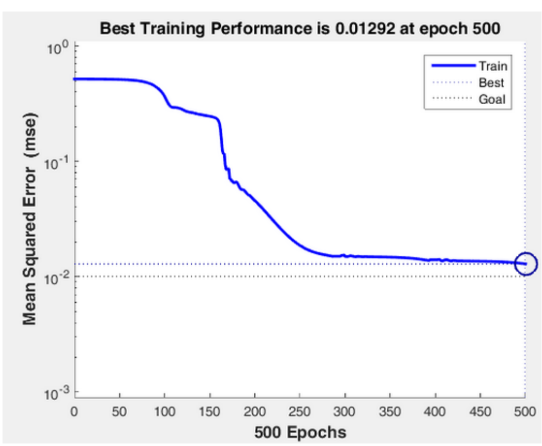

Fig.10. training curve base on BP

Table 2 shows the different result under different network parameters

Case	Hidden nodes	Permitted error	Learning rate	Epoch	Accuracy(100%)
1	3	0.01	0.01	1241	94.286
2	6	0.01	0.01	1147	94.286
3	9	0.01	0.01	1067	94.286
4	3	0.005	0.01	1196	94.286
5	3	0.01	0.005	583	97.143
6	3	0.01	0.5	1159	94.286
7	3	0.3	0.3	43	28.571
8	3	0.05	0.3	111	94.286
9	3	0.3	0.05	97	71.429
10	6	0.3	0.05	96	54.286

VI. Conclusion

Based on the characteristics of fire image of forest fire, this paper proposes a method to identify the existence of forest fires by using three effective characteristic parameters: flame color, area and the circle degree of edge, combined with BP neural algorithm. The recognition rate is about 94%, and the training time is about 250 times to achieve convergence. The computation speed is only 0.01292 seconds. It is obviously better than not using the BP algorithm.The next step is how to use a small number of samples to achieve better training results.

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