Image edge detection for Furnace Flame Based on Section Mutation Glowworm Swarm Algorithm

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Abstract

In view of the gray change of furnace flame, the problem of edge detection cannot be detected by the traditional edge detection algorithm. This paper proposes the phase variation of firefly algorithm to detect image edge of power plant boiler furnace flame, the algorithm adopts the method of phase variation of firefly algorithm is improved so that it can be bound out of the local extreme point, converge to the global extremism. Firstly, the gradient value matrix of gray scale image is obtained by first order derivative of gray level image matrix, and then using the phase variation firefly algorithm, which is based on the search area to find other firefly, and to realize the maximum gradient of search image. Edge detection simulation results show that the algorithm not only can detect the image edge accurately, but also improve the convergence speed and has good adaptability, therefore its application in image edge detection is feasible and effective

Keywords: Furnace flame; section mutation; glowworm swarm algorithm; edge detection

1. INTRODUCTION

The combustion process monitoring technology plays an important role in the development of combustion theory and technology. The flame contains plentiful combustion information, the shape, structure and location which will affect combustion stability and safety directly. Therefore, effectively on flame shape, structure and position analysis is a very important issue in some fields of fire prevention and monitoring, the safe operation of the boiler and combustion control. The digital image processing technology is used to analyze and process the flame digital image, and the continuous on-line monitoring of the combustion state can be realized by extracting the features of the image. Edge detection is a prerequisite for the accurate extraction and analysis, which will affect the flame state recognition rate. It can be used to describe the shape of the flame more accurately. Consequently, the flame image edge detection in the monitoring of the flame, analysis and identification of flame burning state and other aspects have important significance (Song and Wu, 2014; Zhang et al., 2015).

The traditional method based on differential operator is a commonly operator in edge detection such as Sobel, Roberts, Prewitt, Laplacian and Canny operator, then it appears a detection method of morphology, fuzzy theory, wavelet transform and neural network based on the edge. The traditional differential edge detection algorithm often has problems of poor adaptability, and fixed threshold. The application of Bionics in edge detection is one of hot issues in the current research, including genetic algorithm, artificial fish swarm algorithm, ant colony algorithm and particle swarm algorithm. Compared with the traditional edge detection algorithm, swarm intelligence algorithm has some advantages,
such as good robustness, good expansibility, good adaptability, fast operation and so on. In this paper, the firefly algorithm is applied to the edge detection of the furnace flame image, using the firefly algorithm to search the maximum gray gradient in the matrix, so as to get the image edge (Liu et al., 2013; Zhang et al., 2015; Shi et al., 2015).

2. GLOWWORM SWARM ALGORITHM

Glowworm Swarm Algorithm was proposed by India scholar Krishnanand et al in 2005, and this algorithm is a swarm intelligence algorithm for simulating the glowworm luminescence behavior of nature. In this algorithm, some biological significance of glowworm luminescence is abandoned, but only the light emitting and attractive feature of glowworm is used to search and optimize other glowworms, which is based on the area of its search area to search and optimize. Each Glowworm is known as an individual, the individual main position has brightness, attractiveness and other attributes. There are two factors affecting the mutual attraction between the fireflies: brightness and attraction. Specifically, the size of the brightness is associated with the location of the firefly, the better the location, the greater the degree of attraction and brightness, furthermore, the attraction also has relationship with the intensity of the light, and the higher the glowworm has a greater probability to attract other individuals to its position (Shang et al., 2014).

\( u_{ij} \) is the glowworm maximum brightness, \( b_i \) is the medium intensity absorption coefficient, \( \varphi \) is arbitrary individual \( i \) and \( j \) relative space distance, The relative brightness of the two individual is:

\[
v = v_0 e^{-k_0}\]

The relative attraction between the two individuals is

\[
v = v_0 e^{-k_0}\]

In this formula, \( v_0 \) is the maximum degree of attraction, \( \varphi \).

\( l_i, l_j \) represent firefly \( i \) and \( j \) relative space distance respectively, \( b \) is step actor, \( random \) is the [0,1] random factors that are uniformly distributed. The individual is attracted to the larger individual, and the position of the position is updated (Chen et al., 2014; Chao et al., 2015; Chen et al., 2014; Du et al., 2013).

\[
l_i = l_i + v \cdot (l_j - l_i) + b \cdot (random - 0.5)\]

3. SECTION MUTATION OF GLOWWORM SWARM ALGORITHM

Set \( \psi = \frac{G - i}{G}, i = 0, 0.5, 1, 1.5, 2, 2.5, \ldots, \frac{G - 1}{2} \)

\( \psi \) indicates the degree of variation along with the evolution of the evolution, \( G \) is maximum number of iterations for the algorithm. When \( \psi = 1 \), express variation of maximum effect, while \( \psi = (G+1)/G \), the variation plays a minimal role. Process individual state of the glowworm \( Y_i \) stage variation: \( Y_i = Y_i + Y_{j \times \varphi \times \psi} \). In this formula, \( \tau \) is variation factor, \( g \) is current iteration number, \( G \) is maximum iteration number. when \( 0 < g < (G/3) \), \( \tau = C(0,1) \), the distribution is the standard Cauchy distribution; when \( (G/3) < g < (2G/3) \), \( \tau = t(g) \),

\( t(g) \) is the number of iterations of the algorithm for the parameters of the degree of freedom \( t \) distribution, when \( (G/3) < g < (2G/3) \), \( \tau = N(0,1), N(0,1) \) is the mean value of 0, and the average variance is 1 Gauss distribution. \( Y_i = Y_i + Y_{j \times \varphi \times \psi} \) based on \( Y_i \) phased increasing of the different distribution of random interference, to make full use of the information of the
current population. So the use of this formula can make the glowworm jump out of the local extreme points of the bound, convergence to the global extreme point. At the same time, it also improves the convergence rate, and the variation of the variation is not without manual intervention. This mutation is combined with the global exploration ability of the Cauchy distribution, the local exploitation ability of Gauss distribution and the medium search ability of the \( \text{t} \) distribution. So it is better to compare the variation of Cauchy mutation, Gauss and \( \text{t} \) distribution whose mutation ability is single (Du et al., 2013).

4. THE EDGE OF THE FURNACE FLAME IMAGE IS EXTRACTED BY USING THE SECTION MUTATION OF GLOWWORM SWARM ALGORITHM.

Image edge gray value of adjacent regions is not continuous, the gradient image edge point gradient non edge point value is high, so artificial mutation glowworm optimization is the process of looking for gray image gradient high process, namely gray image gradient high point is the optimal solution.

The gray image is divided into 10*256 matrix, and then the glowworm is randomly distributed in 10*256 gray image pixels, and will be in the area of glowworm’s value set 255. The brightness of the glowworm by the objective function value of the decision, the objective function is the gray gradient of section mutation of glowworm swarm value minus the gray level threshold.

The gradient of the image pixel gray value is the gray image of adjacent rows and the adjacent column of pixels are subtracted, and then will reduce the values are added. In this paper, the gradient of the image pixel gray value as parameters of the object function and its gradient is calculated as follows.

\[ M \text{ is Gray scale image, } x_{ij} \text{ is } M \text{ grey value, the formula is} \]

\[ M = \begin{bmatrix}
    x_{11} & x_{12} & \cdots & x_{1n} \\
    x_{21} & x_{22} & \cdots & x_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    x_{n1} & x_{n2} & \cdots & x_{nn}
\end{bmatrix} \]

\[ M_1 \text{ is obtained by subtracting adjacent two line of the gray image; } M_2 \text{ is obtained by subtracting two adjacent columns of the gray image.} \]

\[ M_2 = \begin{bmatrix}
    x_{11} \\
    x_{21} \\
    x_{n1}
\end{bmatrix} \]

By adding \( M_1 \text{ and } M_2 \), the gradient value of gray image is obtained by \( M' = M_1 + M_2 \).

Algorithm steps:

(1) Initialization basic parameters: the number of fireflies, luciferase, the rate of change in the neighborhood, the fitness function, bulletin boards and other initialization parameters;

(2) Update the value of firefly luciferase, chose the number of fireflies within the range of firefly decision, and set the value of fireflies is 255;

(3) In the firefly motion stage, calculate firefly collection for each neighbor firefly, and select direction of movement of firefly, updates the location and the decision region radius.
(4) Compare currently glowworm fitness function values and the value of bulletin board; take the best value to the bulletin board.

(5) If the bulletin board has no change in the course of two consecutive, or changes little. Then go to step 6, otherwise go to step 7;

(6) Use the Optimal Firefly replacing the current population of the worst fireflies firefly with the bulletin board, then intermediate state goes to phase variation;

(7) Termination condition: maximum number of iterations has been reached or not, if not satisfied, go to step 2, swarm optimization process of the next generation of fireflies; otherwise, go to step 8;

(8) The algorithm terminates: output the location of bulletin board fireflies and the objective function value

Parameter settings:

<table>
<thead>
<tr>
<th>Glowworm Number</th>
<th>The maximum number of iterations</th>
<th>Control luciferase value</th>
<th>Neighborhood threshold</th>
<th>The initial silver pixel values</th>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>180</td>
<td>0.4</td>
<td>5</td>
<td>5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

5. EXPERIMENTAL RESULTS

To verify the performance of glowworm edge detection algorithm compared using Sobel, Roberts, canny operator with the proposed method. The results show that the author proposed method has better edge detection, get clearer edge detection, has a more complete outline, more accurate positioning. Due to space limitations, three types of lena image has been the chosen, and use four accompanying furnace flame image as a simulation image. Fig. 4 to 6 are given for pieces of the original gray image, using the above-mentioned four kinds of methods to obtained edge image. Though large number of tests, parameter settings shown in the above table, the same experimental conditions.

Figure 1 shows the results of edge detection with the three types of lena image using the method described above
As can be seen from the figure, using canny method detected the edge which is rich detail, but some edge contour is not clear, vulnerable to interference background impurities, excessive extraction of details, and the method do not conducive to the subsequent processing; using Robert method, the detected outline edge is clear, interference of impurities is small by background. But detected edge is incomplete details, outline is not complete, and some edges could not be detected (such as hair, et al); with respect to the wavelet modulus maxima method, using Sobe detected more detail of edge, by the impurity background interferences; the proposed method detected edge outline clearer by little background interference of impurities, rich details, features more obvious, and make a foundation for the subsequent conduct accurate feature extraction.

The process of Flame image acquisition, transmission and handling, will be affected by the external environment, the system itself, and many other aspects of human factors, inevitably the method has noise. From the more representative of flame image, Figure 2 performed the result using Sobel, Roberts, canny operator and edge extraction algorithm of this article. From Figure 1 we can see that Canny method and Sobel method are sensitive to noise. Within edge detection the methods also bring too multi-extracted impurities caused by noise; anti-noise performance of Robert methods is better than Canny method, but it losts some of the edge information; Sobel edge morphological method detects the result which is not discontinuous, and anti-noise effect is not good; this method of this article is effective to inhibit the noise, and the outline of resulting image edges is still clearly and full, rich detail, and the distinctive characteristics is obvious. So the method of this article can not only detect the edge of the flame image better, and can effectively suppress noise.

**Figure 1** Three kinds of lena image edge detection results
Figure 2 Flame image edge detection result

Verify the validity of the peak signal-to-noise ratio results, the image without noise image edge detection of the image size, image denoising of image edge detection, while the peak signal-to-noise ratio is

\[ P_{PSNR} = 10 \times \log \frac{M \times N \times 255^2}{\sum_{i=1}^{N} \sum_{j=1}^{M} [I(i,j) - f(i,j)]} \]

Comparison of four methods is showed in table 1

<table>
<thead>
<tr>
<th>Method</th>
<th>Noise Density</th>
<th>Noise Density</th>
<th>Noise Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canny Method</td>
<td>4.733 7</td>
<td>3.613 4</td>
<td>3.102 3</td>
</tr>
<tr>
<td>Sobel Method</td>
<td>3.865 7</td>
<td>3.412 1</td>
<td>3.001 3</td>
</tr>
<tr>
<td>Rober Method</td>
<td>3.932 7</td>
<td>3.628 1</td>
<td>3.002 3</td>
</tr>
<tr>
<td>Own Method</td>
<td>5.432 3</td>
<td>5.013 2</td>
<td>4.801 1</td>
</tr>
</tbody>
</table>

The results show that the peak signal to noise ratio of this method is better than the other 3 methods.

Comparing the segmentation time
Table 2 Segmentation time

<table>
<thead>
<tr>
<th>image</th>
<th>Canny Algorithm</th>
<th>Sobel Algorithm</th>
<th>Robert Algorithm</th>
<th>Own Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>5632.0</td>
<td>5331.0</td>
<td>5475.0</td>
<td>5672.0</td>
</tr>
<tr>
<td>b</td>
<td>4879.0</td>
<td>4219.0</td>
<td>4972.0</td>
<td>4971.0</td>
</tr>
<tr>
<td>c</td>
<td>5863.0</td>
<td>5564.0</td>
<td>5536.0</td>
<td>5966.0</td>
</tr>
<tr>
<td>d</td>
<td>5974.0</td>
<td>5492.0</td>
<td>5603.0</td>
<td>5964.0</td>
</tr>
</tbody>
</table>

In terms of operation speed, comparing the running time of the 4 methods are shown in Table 2. From the test results it can be seen that although the Sobel method has a relatively short running time, some edge contour is not clear, which is easy to be interfered by background impurities and is not conducive to the follow-up processing. The running time of this method is slightly longer than the Canny, Sobel, Robert method, but it can obtain better edge detection effect than the above mentioned methods, and it can be used in high frequency and low frequency parallel processing, and can meet the requirements of real-time and accurate detection.

6. CONCLUSIONS

In this paper, the edge detection is carried out by using the section mutation of glowworm swarm algorithm, and simulation experiments show that the algorithm can effectively detect the image edge. Compared with the traditional Sobel, Roberts and canny, the proposed algorithm can not only suppress the background noise effectively, but also can improve the accuracy of image edge detection, and has the advantages of high robustness, which will have a broad application prospect in image edge detection.

7. REFERENCE


