Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

A Threshold Segmentation Method for Infrared Image of High Speed Combustion Field

Yong Zhao[1], Guolu Ma[2]*, Zijun Song[1,3], Anding Li[4]
[1]Aviation key Laboratory of Science and Technology on Altitude Simulation, Mianyang, 621700, China
[2]Ministry of Education Key Laboratory of Testing Technology for Manufacturing Process, Southwest University of Science and Technology, Mianyang 621010, China
[3]Department of Engineering Mechanics, Tsinghua University, Beijing 100084, China
[4]School of Mechanical Engineering, Yangtze University, Jingzhou 434023, China
*Corresponding Author.

Abstract:

In the temperature analysis of high speed combustion Field, the infrared image should usually be segmented with multi thresholds on the basis of analysis target adaptively. However, the traditional image segmentation method can hardly satisfy the requirement of separating different temperature areas from the high speed combustion field. According to the characteristics of the high speed combustion field, a multi-threshold segmentation method is put forward. The method is based on the histogram analysis, which can segment the infrared image effectively by integrating the FCM algorithm in it. The image analysis results show that the method can fulfill the requirement of the temperature analysis of high speed combustion field, and is suitable to promote in the relative fields.

Keywords: *High speed combustion field, Temperature analysis, Threshold segmentation, Fuzzy adaptive segmentation.*

I. INTRODUCTION

In recent years, flight delays and military aircraft grounding events caused by engine failure have occurred from time to time. The severity of the harm, the complexity of the state and the difficulty of monitoring have been widely recognized by researchers in the aviation field. As a large-scale equipment with high requirements for safety and reliability, due to the complexity of technology and structure, the on-line monitoring and analysis of aeroengine status has always been an important topic related to flight safety, which is directly related to the economy and safety of air transportation enterprises and the combat capability of aviation forces. Therefore, it is of great significance to monitor the running state of aeroengine in the production, test and actual use of aeroengine.

According to statistics, the failure of aeroengine gas circuit components accounts for more than 90% of the whole machine failure, which is the main cause of safety events such as air parking [1]. At present, infrared image analysis technology [2,3] is a common method in Aeroengine gas path condition monitoring. By analyzing the temperature distribution of aeroengine high-speed combustion field and

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

judging the health status of parts in the gas path according to the analysis results, it can provide a strong guarantee for the safe operation of aeroengine.

In the temperature analysis of high-speed combustion field, it is usually necessary to segment the infrared image of combustion field by adaptive multi threshold according to the analysis target. Image segmentation is to divide the image into several non overlapping regions according to some consistency attributes in the image, so as to effectively separate the target analysis region from the image background. Because the high-speed combustion field image is a heat source image, the signal strength is weak, the target and boundary in the image are not very clear, and there is no obvious shape, size, texture and other information to be used. Therefore, the traditional image segmentation algorithms such as threshold segmentation, edge detection and region segmentation are often difficult to meet the requirements of high-speed combustion field temperature analysis and achieve effective segmentation of different temperature regions [4].

According to the characteristics of infrared image, scholars at home and abroad have done a lot of research on infrared image segmentation.Among them, Tong, Kuangwei and others used Otsu- Grabcut algorithm to segment the infrared image and proposed a detection method for pipeline leakage of underground air compressor [5]; Guo, ZK proposed an adaptive infrared image segmentation algorithm based on fspcnn according to the information processing mechanism of human neural system [6]; Robitaille, JF and others used MnGSeg analysis technology to effectively separate the analysis target from the infrared image background [7]; Wang Xiaofei and others proposed an intuitionistic fuzzy c-means clustering algorithm based on distribution information for infrared image segmentation of power equipment, which solves the problems of low clustering accuracy, poor detail retention and large time complexity of traditional algorithms [8]; Wang Xiaofang and others combined linear spectral clustering algorithm (LSC), Otsu algorithm and maximum similarity region merging algorithm (MSRM), and proposed a power equipment infrared image segmentation method under complex background [9]; Wang Kun and others proposed an Improved Markov random field segmentation algorithm combined with game theory to solve the problems that the traditional chip heating region extraction method needs manual intervention and the segmentation effect is not ideal [10]. According to the specific characteristics of research objects in different fields, the above algorithms put forward corresponding solutions and achieved good segmentation results. However, the above algorithms also have some limitations. They are only suitable for threshold segmentation of infrared image in specific occasions, and can not meet the requirements of adaptive segmentation of different temperature regions in high-speed combustion field.

At present, fuzzy c-means clustering (FCM) [11-13] algorithm is generally used for threshold segmentation of infrared images. Because the standard FCM algorithm has low clustering accuracy, high time complexity and poor robustness to noise. According to the characteristics of temperature analysis of high-speed combustion field, this paper proposes a threshold segmentation method of infrared image of high-speed combustion field. This method can realize fuzzy adaptive segmentation of infrared image based on histogram analysis combined with FCM algorithm.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

II. TEMPERATURE ANALYSIS FLOW OF HIGH SPEED COMBUSTION FIELD

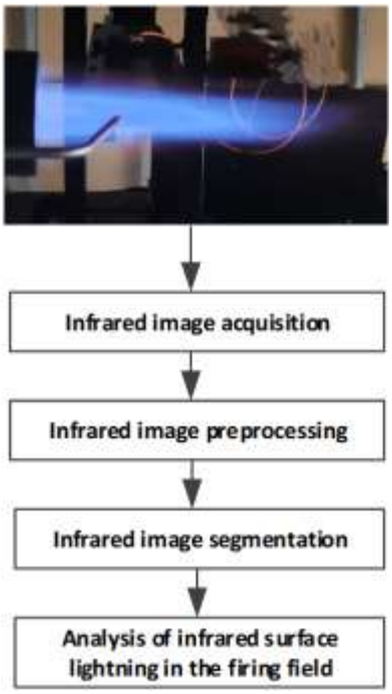


Figure. 1 Analysis process of high-speed combustion field

The main task of temperature analysis of high-speed combustion field is to find the distribution law of temperature field of high-speed combustion field under different working states, realize the on-line monitoring of equipment working state, timely detect potential faults in the working process of equipment, and ensure the safe and stable operation of equipment through the processing and analysis of infrared images. As can be seen in picture. 1, the temperature analysis process of high-speed combustion field mainly includes infrared image acquisition, infrared image preprocessing, infrared image segmentation and infrared image analysis. In the process of temperature analysis of high-speed combustion field, firstly, the infrared CCD camera needs to be used to collect the infrared image of combustion field. Then the infrared image preprocessing algorithm is used to eliminate the image noise and ensure the consistency and uniformity of image brightness. And then it is segmented according to the color characteristics of infrared images of different combustion fields. After separating different temperature regions, we analyze its size and shape, and finally compare the analysis results with the indicators under the normal working state of the equipment, so as to judge the current operation state of the equipment.

2.1 Infrared Image Acquisition

The main task of infrared image acquisition is to obtain high-quality infrared images of high-speed combustion field and ensure that different temperature regions in the combustion field can be segmented correctly. In the process of infrared image acquisition, it should be ensured that the acquired infrared image has small distortion, clarity and low noise; Moreover, the combustion field should be in an

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

appropriate position in the image to reduce the influence of optical distortion at the edge of the lens on the imaging quality; At the same time, the exposure time of the camera should be set at an appropriate value to reduce the motion blur caused by the dynamic change of the combustion field; In addition, the brightness, contrast and saturation of infrared image should meet the requirements of combustion field temperature analysis through the control and adjustment of ambient light.

At present, the acquisition of infrared image of combustion field generally adopts area array CCD camera, which usually achieves better imaging effect than CMOS camera. In addition, compared with the linear array camera, the area array camera is more suitable for infrared image acquisition of high-speed combustion field because it can obtain all image information of combustion field in a single imaging, has fast acquisition speed, and can accurately obtain the morphological information of different temperature regions.

2.2 Infrared Image Preprocessing

In the acquisition process of infrared image of high-speed combustion field, it is easy to be affected by dust, ambient light, electromagnetic interference and mechanical vibration on the lens surface, which will inevitably introduce noise and interference, resulting in the decline of image quality. The purpose of infrared image preprocessing algorithm is to eliminate the noise and interference in the image as much as possible, enhance the image quality and ensure the correct results of subsequent image segmentation. Common noise reduction methods include spatial filtering method [14] and frequency domain filtering method [15]. Spatial filtering method is a method that directly processes the pixels of the image by using spatial filter, which is selecting a certain size neighborhood template as the convolution core, moving the template row by row and column by column along the image to complete the convolution operation of all pixels, so as to filter the noise. The frequency domain filtering method first transforms the image from spatial domain to frequency domain through frequency domain transformation, then filters the high-frequency signal with frequency domain filter, and finally obtains the filtered image through the corresponding inverse frequency domain transformation. Because the time complexity of spatial filtering method is relatively low, it is more suitable for infrared image processing of high-speed combustion field.

Image gray transformation is another image preprocessing method to enhance image quality. In the process of infrared image acquisition, the brightness of infrared image of combustion field will be different due to the interference of stray light or the change of field environment. The brightness of the infrared image of the combustion field can be kept consistent by using the image gray transformation, so as to improve the stability of the infrared image segmentation algorithm.

2.3 Infrared Image Segmentation

The main task of infrared image segmentation is to divide different temperature regions of high-speed combustion field and separate each temperature region from the image background. Image segmentation has always been a hot issue in image processing. Although the current image segmentation algorithms

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

have more than 1000 kinds, they have not formed a complete theoretical system. Most image segmentation algorithms have certain limitations. They can achieve good results only when solving specific problems and are not universal. At present, the most commonly used segmentation methods include threshold segmentation, edge detection, region segmentation, Morphological Watershed Segmentation and segmentation based on special theory. In the temperature analysis of high-speed combustion field, a single segmentation algorithm is generally difficult to achieve good segmentation results. Therefore, In view of the characteristics of temperature analysis of high-speed combustion field, this a multi threshold segmentation method for infrared image of high-speed combustion field. This method can realize fuzzy adaptive segmentation of infrared image based on histogram analysis and FCM algorithm.

2.4 Infrared Image Analysis of High Speed Combustion Field

After separating the different temperature regions of high-speed combustion field, it is necessary to extract the gray and geometric features of each region. Gray features mainly include gray maximum, gray minimum, gray amplitude, gray mean, variance, etc; Geometric features mainly include centroid, area, perimeter, distance, length width ratio, duty cycle, roundness, rectangularity, eccentricity, etc. The main task of infrared image analysis of high-speed combustion field is to describe these image features with feature vectors, establish a sample database under various working states, obtain a classifier to judge the current running health state of the equipment through training, analyze the working state of the equipment according to the classification results of the classifier, predict the potential failure hazards in the working process of the equipment, and ensure the safe and stable operation of the equipment.

III. FUZZY ADAPTIVE SEGMENTATION OF HIGH SPEED COMBUSTION FIELD IMAGE

3.1 Fuzzy C-Means Clustering Segmentation Algorithm

3.1.1 Basic principle of fuzzy c-means clustering segmentation

Fuzzy C-means (FCM) clustering algorithm is an important fuzzy clustering algorithm. Due to its strong adaptability, it can be used to process images with fuzzy edges and relatively low contrast. It has been widely used in infrared image segmentation. The basic idea of FCM clustering segmentation algorithm is to iteratively obtain the clustering center and the membership relationship between the pixel value of each point of the image and the clustering center, so as to minimize the objective function, so as to realize the optimal image segmentation. The objective function of FCM clustering segmentation algorithm can be expressed by equation (1) as follows:

$$J = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} (x_i - c_j)^2 \tag{1}$$

Where, i and j are the indexes of pixel points and cluster centers respectively; N,C is the number of pixels and clusters respectively; m is the fuzzy weighted index, m[1, ∞]; xi is the pixel value of pixel point

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

i; cj is the pixel value of cluster center j; Uij is the membership degree of pixel i relative to cluster center j.

The constraint function of membership is:

$$\sum_{k=1}^{C} u_{ik} = 1, \qquad i = 1, 2, \ldots, N \tag{2}$$

Where, i and k are the indexes of pixel points and cluster centers respectively; Uik is the membership degree of pixel i relative to cluster center k.

FCM clustering segmentation algorithm can be regarded as the membership degree of each pixel, and the minimum of objective function (1) is obtained under constraint (2). The iteration formula (3) of membership Uij and the iteration formula (4) of clustering center cj can be obtained by using Lagrange multiplier method as follows:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C} \left(\frac{x_i - c_j}{x_i - c_k} \right)^{\frac{2}{m-1}}} \tag{3}$$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m x_i}{\sum_{i=1}^{N} u_{ij}^m} \tag{4}$$

When FCM algorithm is used for clustering segmentation, the termination conditions of iteration can be represented by formula (5) as follows:

$$\max_{i,j} \{ \left| u_{ij}^{(k+1)} - u_{ij}^{(k)} \right| \} < \varepsilon \tag{5}$$

In the formula, a small quantity between 0 and 1 represents the admissible error of subordination degree. k indicates the number of iterations.

Under the constraints of Eq. (2), the algorithm uses Eq. (3) and (4) to iterate. When the termination condition of the iteration described in Eq. (5) is satisfied, the iteration stops and an optimal solution of the objective function (1) can be obtained.

3.1.2 Analysis of algorithm for fuzzy C-means clustering segmentation

According to the basic principle of fuzzy C-means clustering segmentation, the basic realization

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

process of the algorithm can be described as follows:

Step 1: Initialize the subordination Uij and satisfy the constraints of Formula (2);

Step 2: Calculate the central cj of cluster by formula (4);

Step 3: Use Formula (3) to calculate the new membership;

Step 4: Iteration termination condition is judged according to formula (5). When the condition is not met, step 2 is returned to continue. When the condition is met, the iteration is terminated and the image is segmented according to the result of the iteration.

From the basic principle and algorithm flow of fuzzy C-means clustering segmentation, it can be seen that the standard FCM algorithm has some obvious disadvantages, which are mainly manifested in the following aspects:

FCM algorithm is sensitive to initial clustering center and easy to get local optimal solution;

The FCM algorithm does not consider the influence of spatial neighborhood information and is sensitive to noise.

FCM algorithm does not consider the different impact of different sample sizes on clustering results.

Therefore, in the temperature analysis of high-speed combustion field, it is necessary to improve and optimize the standard FCM algorithm according to the characteristics of infrared image, so as to get a better segmentation effect.

3.2 Improved Fuzzy C-Means Clustering Segmentation Algorithm

3.2.1 Selection of Initial Clustering Center

Marking FCM algorithm needs to specify the number of initial clustering in advance and calculate the initial clustering center by randomly initialized membership degree. This method of selecting the initial clustering center limits the convergence speed and iteration accuracy of the algorithm and is easy to fall into local optimum. The method of weighted minimum maximum distance can be used to improve the selection of this initial clustering center. This method first calculates the histogram of the image, then uses expression (6) to get the normalized weight wh based on the histogram, and finally determines the initial clustering center according to the distance expression (7) between the sample and the clustering center.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

$$w_h = \frac{h_t}{\sum_{t=0}^{255} h_t} \quad (6)$$

$$d_{tt'} = w_h \left| t - t' \right| \quad (7)$$

In Formulas (6) and (7), ht (t=0, 1,..., 255) is a histogram corresponding to each gray value; t' is a known clustering center; t is a sample point of the gray value to be determined.

The specific process of selecting initial cluster center by weighted minimum maximum distance method is as follows:

Calculate the histogram of the image, and select the gray value of the histogram ht to obtain the maximum value as the first clustering center t1' ;

According to the distance formula (7), it is determined that the gray value sample point farthest from t1' is the second clustering center t2';

(3) Calculate the weighted distances di1 and di2 between each gray value sample point and t1', t2' one by one, take di= min (di1, di1), and determine t3 'from the maximum value of each sample distance d max = max (di);

(4) If the number of cluster centers meets the requirements, stop the search process. Otherwise, calculate the distance between the remaining samples and the known cluster center, and determine the new cluster center according to the same weighted maximum and minimum distance criterion.

3.2.2 Neighborhood weighted fuzzy c-means clustering segmentation

Image filtering algorithms have some limitations. After noise reduction, there will still be some noise in the image. Because the standard FCM algorithm does not consider the relationship between the current pixel gray value and adjacent pixels, it is very sensitive to noise. In the process of clustering, if the pixels with large neighborhood difference get smaller weight and the pixels with small neighborhood difference get larger weight, the influence of effective noise points on clustering results can be reduced. The weight can be calculated by Gaussian function as follows:

$$w'(x, y) = \frac{1}{mn-1} \sum_{\substack{(s,t)\in S_{xy}, \\ (s,t)\neq(x,y)}} e^{-(g(s,t)-g(x,y))^2} \quad (8)$$

Where Sxy is the neighborhood of the image at point (x, y); m and n are the width and height of the neighborhood respectively; g (s, t) is the gray value of any point in the neighborhood Sxy; g (x, y) is the

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

gray value of the image at point (x, y). Normalize the weight w'(x, y) within the neighborhood to obtain:

$$w(x,y)=\frac{w'(x,y)}{\sum_{(s,t)\in S_{xy}} w'(s,t)} \tag{9}$$

Introducing the histogram weighting coefficient wh and neighborhood weighting coefficient into the objective function (1), we can get:

$$J=\sum_{i=1}^{N}\sum_{j=1}^{C} w_{hj} w_j u_{ij}^m (x_i-c_j)^2 \tag{10}$$

Under constraint condition (2), the minimum value of objective function (10) is obtained by Lagrange multiplier method. Under constraints:

$$F=\sum_{i=1}^{N}\sum_{j=1}^{C} w_{hj} w_j u_{ij}^m (x_i-c_j)^2+\sum_{i=1}^{N}\lambda_i(1-\sum_{k=1}^{C}u_{ik}) \tag{11}$$

F calculates the partial derivative of all input variables Uij and makes it zero, which can meet the necessary condition for obtaining the minimum value of equation (10), that is:

$$\frac{\partial F}{\partial u_{ij}}=mu_{ij}^{m-1} w_{hj} w_j (x_i-c_j)^2-\lambda_j=0 \tag{12}$$

The iterative formula (13) of membership Uij is obtained from (12) as follows:

$$u_{ij}=\left[\frac{\lambda_j}{mw_{hj}w_j(x_i-c_j)^2}\right]^{\frac{1}{m-1}} \tag{13}$$

F pair λj find the partial derivative and make it zero,we can get:

$$\frac{\partial F}{\partial \lambda_j}=1-\sum_{k=1}^{C}u_{ik}=0 \tag{14}$$

Bring (13) into (14) to get:

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

$$\left(\frac{\lambda_j}{m w_{hj} w_j}\right)^{\frac{1}{m-1}} = \frac{1}{\sum_{k=1}^{C}\left(\frac{1}{x_i - c_k}\right)^{\frac{2}{m-1}}} \tag{15}$$

By introducing (15) into (13), the iterative formula (16) of membership Uij can be obtained as follows:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{x_i - c_j}{x_i - c_k}\right)^{\frac{2}{m-1}}} \tag{16}$$

F obtains the partial derivative of cj and makes it zero,we can get:

$$\frac{\partial F}{\partial c_j} = 2\sum_{i=1}^{N} w_{hj} w_j u_{ij}^m (x_i - c_j) = 0 \tag{17}$$

According to (17), the iterative formula (18) of the cluster center cj can be obtained as follows:

$$c_j = \frac{\sum_{i=1}^{N} w_{hi} w_i u_{ij}^m x_i}{\sum_{i=1}^{N} w_{hi} w_i u_{ij}^m} \tag{18}$$

3.2.3 Analysis of improved fuzzy c-means clustering segmentation algorithm

The basic process of fuzzy C-means clustering and segmentation algorithm based on improvement can be described as follows:

Step 1: Calculate the initial cluster center using the histogram-based weighted minimum maximum distance method, as well as the histogram weighting coefficient wh;

Step 2: Consider the influence of each pixel in the neighborhood, calculate the neighborhood weighting coefficient w of the current pixel according to the formulas (8) and (9);

Step 3: Calculate the membership matrix using equation (11);

Step 4: According to the resulting membership matrix, calculate the new cluster center using the formula (12);

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

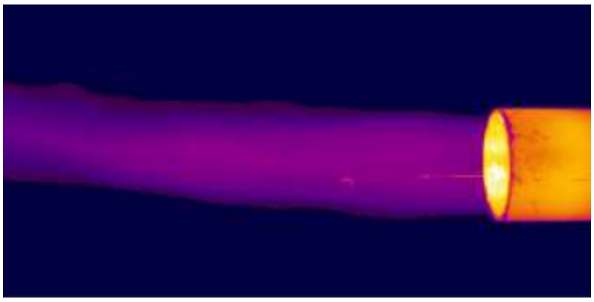
Step: 5: Calculate the new membership matrix from the newly obtained cluster center according to equation (11);

Step 6: Compare the two membership matrices and make an iterative termination condition judgment according to equation (5), return to step 4 to continue when the condition is not met, terminate the iteration when the condition is met, and segment the image according to the iteration result.

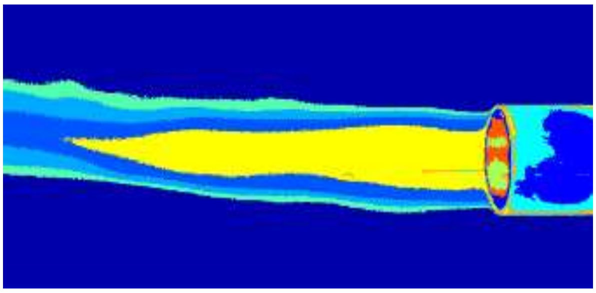
Since the improved fuzzy C-means clustering and segmentation algorithm uses the histogram-based minimum maximum distance method to determine the initial cluster center, the iteration time can be greatly reduced, the operation efficiency of the program can be improved, and the global optimal solution of the objective function can be obtained more easily. At the same time, considering that sample size will have a certain influence on the clustering effect, the histogram weighting coefficient is introduced in the objective function. In addition, considering the influence of pixels in the neighborhood on the clustering effect, the algorithm also adds a neighborhood-weighted coefficient to the objective function.

In the temperature analysis of high-speed combustion field, the improved fuzzy C mean algorithm is used to cluster and segment the infrared image, which can effectively overcome the shortcomings of the standard FCM algorithm and realize the effective separation of each temperature analysis area from the image background.

IV. EXPERIMENTAL ANALYSIS

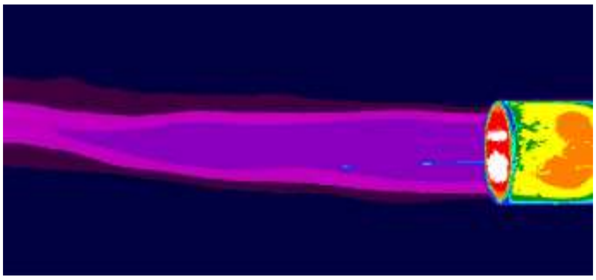


(a) Raw infrared image of high-speed combustion field

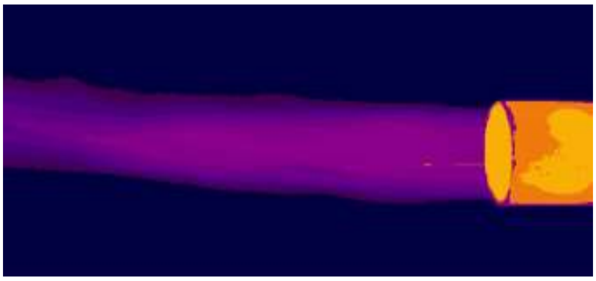


(b) The result of clustering segmentation using K-means algorithm

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022



(c) The result of clustering and segmentation using the standard FCM algorithm



(d) The result of clustering and segmentation using the improved fuzzy C-means algorithm

Figure. 2 Comparison of segmentation effects of different clustering algorithms for infrared images of high-speed combustion fields

As can be seen from Fig. 2 (a), the boundary between different temperature regions in the original infrared image of high-speed combustion field is very fuzzy. It is often difficult to achieve good segmentation results by using traditional image segmentation algorithms such as threshold segmentation, edge detection and region segmentation, which can not meet the requirements of temperature analysis of high-speed combustion field. Therefore, this article mainly compares the improved fuzzy c-means clustering segmentation algorithm with the standard FCM algorithm and the commonly used K-means clustering segmentation algorithm.

Fig. 2 (b), (c) and (d) are the clustering segmentation results obtained when the number of clusters is 10. As can be seen from Fig. 2 (b) and Fig. 2 (c), both the k-means algorithm and the standard FCM algorithm are vulnerable to the interference of noise points, and the segmented region can not focus well on the combustion flame to be analyzed, so it can not achieve the expected segmentation effect. Compared with the k-means algorithm, the edge of FCM algorithm is smoother, which is convenient for subsequent image feature extraction. It is more suitable for clustering and segmentation of images with fuzzy boundaries such as infrared images of combustion field. In the actual use process, the number of clusters and fuzzy weighting index of target images are adjusted appropriately according to the requirements of temperature analysis. It can improve the segmentation effect to a certain extent. However, because the initial membership of the standard FCM algorithm is randomly specified, the image segmentation effect will be unstable. The results may be different when the same image is segmented twice. In addition, because the standard FCM algorithm does not consider the influence of neighborhood pixels, the segmentation effect is greatly affected by noise points. It can be seen from Fig. 2 (d) that the improved

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

fuzzy c-means algorithm can better focus on the combustion flame, clearly subdivide each temperature region, and achieve good segmentation effect. Because the algorithm uses the minimum and maximum distance method based on histogram to determine the initial clustering center, the iteration time of the program is greatly reduced and the operation efficiency of the program is improved. In addition, due to the introduction of histogram weighting coefficient and neighborhood weighting coefficient into the objective function, the algorithm can also effectively solve the problems that the traditional FCM algorithm is easy to fall into local optimization, is sensitive to noise, and does not consider the impact of sample size on clustering effect.

V. CONCLUSION

The threshold segmentation method proposed in this paper has been successfully applied in the temperature analysis of high-speed combustion field. It can effectively segment the infrared image of combustion field and realize the effective separation of each temperature analysis region and infrared image background. The algorithm uses the minimum and maximum distance method based on histogram to determine the initial clustering center, which can greatly reduce the iteration time and improve the operation efficiency of the program. At the same time, the histogram weighting coefficient and neighborhood weighting coefficient are introduced into the objective function, which can effectively overcome the shortcomings of the traditional FCM algorithm, such as being easy to fall into local optimization, being sensitive to noise, and not considering the impact of sample size on the effect of cluster analysis. The experimental results show that this method can meet the requirements of temperature analysis of high-speed combustion field and is suitable for application and popularization in related fields.

REFERENCES

[1] Liu P P. Research on Method and System of Electrostatic Monitoring for Gas Path Faults of Aero Engine. Nanjing University of Aeronautics and Astronautics, (2013)

[2] Zhou M M. ECT-based Image Reconstruction Algorithm Study of Aero-engine Gas Detection System. Civil Aviation University of China, (2015)

[3] Mei F, Jiang Y, Chen S G, et al. Infrared imaging prediction model for aero-engine exhaust plume. Laser & Infrared, 42(8): 909-913(2012).

[4] Liu G, Zhang D. Infrared Imaging Guidance Image Processing Technology. Beijing: Science Press, (2016).

[5] Tong K, Wang Z, Si L, et al. A Novel Pipeline Leak Recognition Method of Mine Air Compressor Based on Infrared Thermal Image Using IFA and SVM. Applied Sciences, 10(17):5991(2020).

[6] Guo Z, Song Y, Zhao Y, et al. An adaptive infrared image segmentation method based on fusion SPCNN. Signal Processing Image Communication, 87:115905(2020).

[7] Robitaille J F, Motte F, Schneider N, et al. Exposing the plural nature of molecular clouds Extracting filaments and the cosmic infrared background against the true scale-free interstellar medium. Astronomy & Astro- physics, 628(2019).

[8] Wang X F, Hu F K, Huang S. Infrared image segmentation algorithm based on distribution information intuitionistic fuzzy c-means clustering. Journal on Communications, 41(05): 120-129(2020).

[9] Wang X F, Mao H M. Infrared Image Segmentation Method for Power Equipment in Complex Background. Infrared Technology, 41(05): 120-129(2020).

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 729-742
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 15 May 2022

[10] Wang K, Zhang K, Wang L, et al. Infrared Image Segmentation Algorithm Based on MRF Combined with the Game-theory. Infrared Technology, 36(10): 801-806(2014).
[11] Zhu Z L, Liu Y J, Zhao Z M. Improved suppressed fuzzy c-means clustering algorithm for segmenting the non-destructive testing image. Chinese Journal of Scientific Instrument, 40(08): 110-118(2019).
[12] Hong X G, Zhou S F. Infrared Image Segmentation of Photovoltaic Panel Based on Fuzzy C-Means Clustering. Computer Systems & Applications, 28(05): 35-41(2019).
[13] Han B, Shi L, Li M X, et al. Research on intelligent processing technology of infrared video image of blast furnace top. Journal of Inner Mongolia University of Science and Technology, 38(01): 8-13(2019).
[14] Xiong H, Gao F, Zhang X, et al. Characteristics and performance of a two-lens slit spatial filter for high power lasers. Optical Communications, 390: 16-21(2017).
[15] Ortolani F, Comminiello D, Scarpiniti M, et al. Frequency domain quaternion adaptive filters: Algorithms and convergence performance. Signal processing, 136:69-80(2017).