

Application of an improved threshold segmentation method in SEM material analysis

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Abstract: Threshold analysis is a common method of image analysis. It is difficult to separate the target from the background with only one threshold method for more complex images. An improved multi threshold segmentation algorithm is proposed based on the characteristics of the SEM material itself. The all completed experimental results show that the algorithm is effective.

1. Introduction

To better study the properties of fiber materials, the designers usually take microstructures of the material with an electron scanning microscope (SEM) to analyze the fiber distribution inside the material. However, the quality of pictures is often not ideal due to various factors. The main performance is that the electric noise is large, and the target and background are blurred, which can cause a lot of trouble for the back work^[1].

The target fiber is extracted from the background in the process of analysis, and at the same time, the noise is minimized while extracting the target. This process is called image segmentation. The target is separated from the background by selecting the appropriate threshold. But it depends on the selection of the threshold^{[2]-[5]}.

The selection of threshold is difficult to select because of the influence of noise and brightness. Such as segmentation algorithm based on SLIC threshold method^[3], segmentation method using automatic threshold^[5], and method of two-dimensional OTSU threshold segmentation^[6].

2. Image pre-process

The original image is shown as figure 1. The brightness distribution is uneven, and the edges and details are blurred. Therefore, the original image is preprocessed and the target is extracted by threshold segmentation then. The purpose of image preprocessing is to retrain noise and improve image quality, which can be carried out in spatial domain, frequency domain and other transform domain. Median filtering is nonlinear processing technique in spatial domain which can eliminate the isolated noises. And it can maintain the edge feature without making the image significantly fuzzy^[7].

The wavelet transform is to preprocess the image to enhance the image in the transform domain. The image is decomposed by 3 layers of wavelet, and a series of wavelet coefficients are obtained. The size of the wavelet coefficients is the same as the original image. Remove the wavelet coefficients that carry the noise, then it is restructured, and the enhanced image is got.



3. Threshold segmentation

Segmentation is the technology and the process of separating a specific target from a specific area. There are many kinds of image segmentation methods, and this paper is based on threshold segmentation. The basic principle of threshold segmentation is to divide image pixels into several categories by setting different characteristic thresholds. Common features including: the grayscale or color characteristics of the original image or the transformation characteristics. Assuming that the original image is $f(x, y)$, the image is divided into two parts according to certain criteria. And the image after segmentation is shown as^[8]

$$g(x, y) = \begin{cases} b_1 & f(x, y) < t \\ b_2 & f(x, y) > t \end{cases} \quad (1)$$

In the formula, $f(x, y)$ is the original image, $g(x, y)$ is the segmentation image and the t is the threshold. The two-value threshold segmentation method is often used to reduce the data and simplify the processing because of the speed requirements.

Global threshold method is to calculate the optimal segmentation threshold, which can be a single threshold or multi-threshold value. The method includes two types, which are point and region methods. The threshold method based on point is studied in this paper.

3.1. Bimodal Method

For images with obvious differences in the gray level of the target and the background, the histogram is usually used to determine the threshold. The images compared with the background usually have histogram with bimodal. The object produces one of the peaks and the background generate another peak in the histogram. And the boundary between the object and the background produces the valley between the two peaks^[9].

When the segment threshold is at the bottom of the valley, image segmentation can achieve the best results. The method is simple and easy to use, but the method cannot be used for the image of the flat wave peak. Moreover, when the image is affected by the noise, the bottom of the histogram is filled, or the target object is close to the peak of the background, so it is difficult to detect the bottom.

3.2. Variance Threshold

The most inter-variance method was proposed by Japanese scholar in 1979, which is a method of adaptive threshold determination, also called OTSU^[10]. It is the grayscale characteristic of the image, divided the image into the background and the target two parts. The larger the variance between the background and the target, the larger the difference between the two parts of the image^[11]. The method is based on the principle of least square method, and its algorithm is simple, which is a convenient and feasible threshold selection method. The algorithm process is as follows:

(1) First, find the highest grayscale in the image ($L - 1$);

(2) Then, each gray level from 0 to $L-1$ is taken as threshold K ;

(3) The probability of the threshold is calculated and the probability is summed over by the weight.

And the average value μ_i of the gray level of the pixel is calculated. It is show as

$$\omega_1 = \sum_{i=0}^k p_i \quad (2)$$

$$\omega_2 = \sum_{i=k+1}^{L-1} p_i \quad (3)$$

$$\mu_1 = \frac{1}{\omega_1} \sum_{i=0}^k i p_i \quad (4)$$

$$\mu_2 = \frac{1}{\omega_2} \sum_{i=k}^{L-1} i p_i \quad (5)$$

(4) Calculate the overall gray value of the image μ , it is shown as;

$$\mu = \sum_{j=0}^{i-1} ip_i \quad (6)$$

(4)The variance σ_B between the two classed is calculated, and the maximum threshold T of the variance is found out.

$$\sigma^2 = \omega_1(\mu_1 - \mu)^2 + \omega_2(\mu_2 - \mu)^2 \quad (7)$$

4. Experimental results

In order to prove the effectiveness of this algorithm, the fiber material image is being tested in the paper. First, the histogram is shown in the figure1. From the histogram, it does not have two peaks, which means the contrast between the target and the background is not obvious. So bimodal segmentation may not be appropriate for this kind of image.

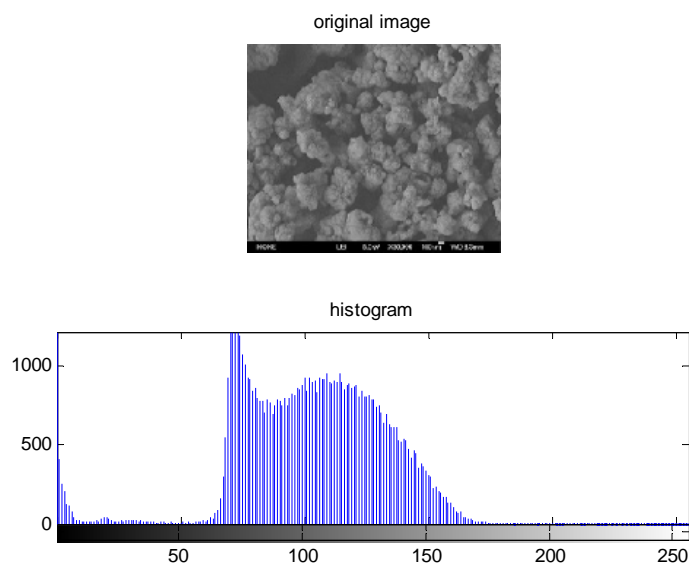


Figure 1. The original image and its histogram

Because the contrast of image is not obvious, the most inter-class variance method is adopted. Firstly, the method is adopted for the image of SEM fiber material. The threshold value is 0.5. The effect is that the edges of the target are submerged in the background. When the threshold is 0.25, the segment effect is even worse. When the adaptive OTSU algorithm is adopted to automatically obtain its threshold value, the image segmentation effect is very good. It is shown as figure 2. The segmentation threshold and time are as shown in Table1.

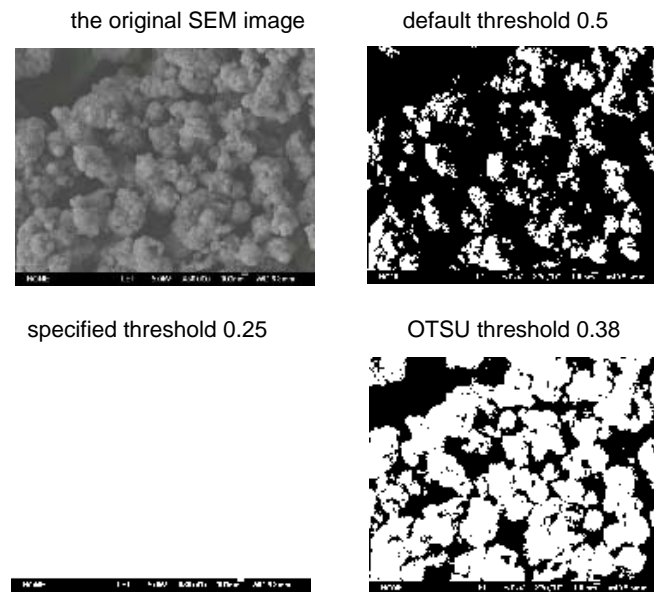


Figure 2. The results of different thresholds

Table 1 comparison of two algorithms parameters

algorithm	Threshold value(normalization)	Segmentation time(s)
Bimodal Method	0.702	0.00188
Variance Threshold	0.38	0.00809

We can see from the table, the time taken by both is very short, but the variance threshold algorithm can better segment the target from the background for the SEM fiber image, which is not obviously compared.

5. Conclusion

Image analysis of fiber materials is a new combination of image processing technology and materials research. The maximum inter-class variance and bimodal threshold are used to extract the edge of the object effectively. The fiber materials is uneven and the edges are blurred. These are all Problems need to solved, and we will do more research in the future.

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