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Improved Threshold-based Segmentation Method for Millimeter Wave Radiometric Image

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***Abstract*—Working all-day and all-weather, the passive millimeter wave radiometer can be used in many fields to detect objects, especially for the concealed objects. With the passive millimeter wave radiometric image processed and analyzed, we can get the shape or the center of the interested object which may be helpful for the following operation. However, some classical segmentation methods can't work well for the passive millimeter wave radiometric image with the existence of transition band near the edge of object. Therefore, we propose a simple improved segmentation method based on the maximum between-class variance and the maximum entropy threshold selection method. To be specific, when finding the right threshold for object segmentation, the difference between the first and second segmentation result based on the maximum between-class variance threshold selection method is first obtained so we get the approximate location of the edge of the target. Then we can get the final threshold for segmentation by applying the maximum entropy method to the obtained local region. The improved method takes not only the advantage of the two threshold selection methods, but also fully considers the global and local information. Experimental result shows that the method has a better segmentation effect for our passive millimeter wave radiometric image and the calculation is relatively less.**

Keywords—millimeter wave; image segmentation; method improvement

I. INTRODUCTION

Passive millimeter wave (PMMW) imaging technology uses the millimeter wave radiometer to detect the millimeter wave radiated energy of the target and the scene. A series of processing is performed after getting the data, such as amplification and finally the received signals can be expressed in the form of image. The pixel value of image reflects the corresponding antenna temperature within the detection coverage. Because of the different radiation characteristic of the target and the background, we can detect and extract the target by analyzing the image. In recent years, PMMW imaging technology is increasingly used in security field. MMW radiometric images can be used to detect weapons and knives, etc. The process of image segmentation and feature extraction is crucial. However, MMW radiometric images have the characteristics of low resolution, blurred edge and the existence of transition band. How to overcome their bad effects on image processing and achieve accurate segmentation, extraction or recognition with less time consumption is the focus in recent years. [1] proposed a fast detection algorithm based on image denoising and classification for MMW radiometric images. [2] proposed a complex morphology self-adaptive filtering algorithm to filter the MMW radiometric image and then detect the edge. [3] combined the maximum between-class variance and genetic algorithm to improve the speed of threshold selection. Then, the final result is obtained by processing the segmented image with the morphological method. These methods are relatively complex. In this paper, in order to study the detection and feature extraction of target in MMW field, we did a simple experiment from which we get the MMW radiometric image of metal target. Then the improved threshold-based segmentation method is proposed, which takes both the local information and global information into consideration and combines the maximum between-class variance method (Otsu) and the maximum entropy threshold selection method [4, 5] to complete the segmentation.

II. RELATED THEORY

The maximum between-class variance method is proposed by Japanese scholar Otsu. Based on the grayscale histogram of an image, the method tries to find the threshold for region segmentation according to the criterion of maximum between-class distance. The basic idea is to divide the image into the background and the target according to a certain threshold. If the target is misjudged as the background, the difference between the background and the target will be smaller, so with the largest variance between the two classes found, we can take the corresponding segmentation threshold as the best threshold. The calculations in detail is as follows:

Assuming that the gray level of the given image is L, the number of pixels of level i is n_i, and the total number of all pixels is N, then the probability corresponding to each gray level i is n_i/N. If we select the level t as the threshold to split the image to part A whose gray value is smaller than t and part B whose gray value is greater than t, then we can calculate the proportion of A and B in the image respectively:

$$\omega_{\mathrm{A}} = \sum_{\mathrm{i}=0}^{t} \frac{n_i}{N} = \omega(\mathrm{t}) \tag{1}$$

$$\omega_{\mathrm{B}} = \sum_{\mathrm{i}=t+1}^{L-1} \frac{n_i}{N} = 1 - \omega(t) \tag{2}$$

If we use μ_A and μ_B to represent the average value of pixels in region A and B respectively, and use μ_0 to represent the average value of pixels of the whole image. Then the between-class variance of region A and region B is:

$$\sigma^2=\omega(\mathrm{t})(\mu_A-\mu_0)^2+(1-\omega(\mathrm{t}))(\mu_B-\mu_0)^2 \tag{3}$$

When t ranges from 0 to $L-1$, the between-class variance varies with t, so the t, which maximizes the between-class variance, is the optimal threshold for the segmentation of the image.

Entropy describes the uncertainty of information. The edge in the image is characterized by the greatest uncertainty. Based on this character the maximum entropy method finds the optimal threshold for the segmentation of given image. Its basic idea is as follows:

Assuming that the gray level of the given image is L, the probability of gray level i is P_i. If the gray level t is selected as the threshold, and the image is divided into two parts: the target O (the part whose gray value is smaller than t) and the background B (whose gray value is greater than t). So for the image, the entropy of target and background respectively are as follows:

$$\begin{aligned} H_o &= -\sum_i \left(\frac{P_i}{P_t}\right)\log\left(\frac{P_i}{P_t}\right) \qquad i=0,1,\cdots t \\ H_B &= -\sum_i \left(\frac{P_i}{1-P_t}\right)\log\left(\frac{P_i}{1-P_t}\right) \quad i=t+1,\cdots L-1 \end{aligned} \tag{4}$$

Where P_t can be calculated by the following formula:

$$P_t = \sum_{i=0}^{t} P_i \tag{5}$$

To calculate the $\omega = H_O + H_B$ corresponding to each gray level in the image, the gray level t that makes ω the maximum is the best threshold for the segmentation.

III. THE PROPOSED METHOD

The proposed method: The Otsu method takes the maximal variance between target and background as a separation criterion and it's suitable for segmentation of images whose gray scale contrast between target and background is great [6]. Converting the data of target detected by the radiometer to a grayscale image, we can find obviously that the target's gray value is quite different from that of the background and it's appropriate to segment the image by using Otsu method to find the optimal threshold. Of course before that we pre-process the image which benefits the later segmentation. However it's not enough and some pixels near the target's edge are wrongly taken as part of the target for the MMW radiometric image has the characteristics of the blurred edge and the existence of transition band. Based on the result, if we try to segment the image of the obtained target for a second time using Otsu method, there will be over-segmentation.

In order to get better segmentation, we subtract the second segmentation result from the first segmentation result so we can get a region which should contain the edge of the target and the transition band. For the obtained small local region, the pixel values are more concentrated. Information entropy is a measure of the degree of uncertainty of random variables. The smaller the value, the smaller the uncertainty and the randomness are. The edge in the image is often the location with greatest uncertainty, so with the help of entropy usually we can find the outline of the image. The one-dimensional maximum entropy image segmentation method is suitable for images with no obvious bimodal histogram distribution [7]. The pixel values of the obtained local region are comparatively concentrated, and it's suitable to select the threshold with maximum entropy method. Therefore, the final threshold is obtained to segment the image with the help of the extracted local information and the maximum entropy threshold selection method. The main process is shown in Figure 1.

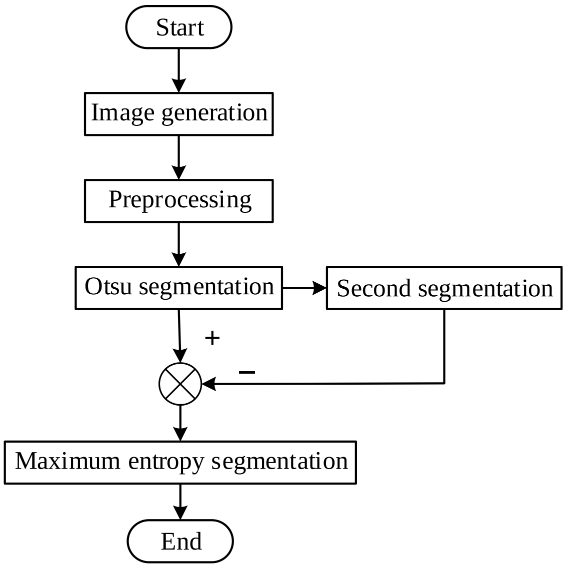

FIGURE I. THE MAIN PROCESS.

IV. EXPERIMENTAL RESULT

The experimental results of metal target are shown in Figure 2. Figure 2a is the optical image which shows the shape of the metal target. Figure 2b is the initial grayscale image converted from the MMW radiation signals and the gray of the metal part is higher. The two are slightly different for the angle and view of imaging are different. Figure 2c shows the image after pre-processing which include filtering and gray transformation. Figure 2d shows the result of the classical Otsu segmentation and it's obvious that it doesn't work well for our MMW image and the target we get is very rough. Figure 2e shows the result of the second segmentation using Otsu method to select a threshold and the target is over-segmented. Figure 2f shows the final threshold segmentation result by applying the maximum entropy method to the local region obtained by subtracting Figure 2e from Figure 2d. Ignoring the imaging error and making a comparison between Figure 2a, Figure 2d and Figure 2f, it's obvious that the segmentation result of the improved method is better than the traditional Otsu segmentation result in Figure 2d and the improved threshold-based method is a relatively simple and ideal method to segment the target from the blurred MMW radiometric image with transition band near the edge of target.

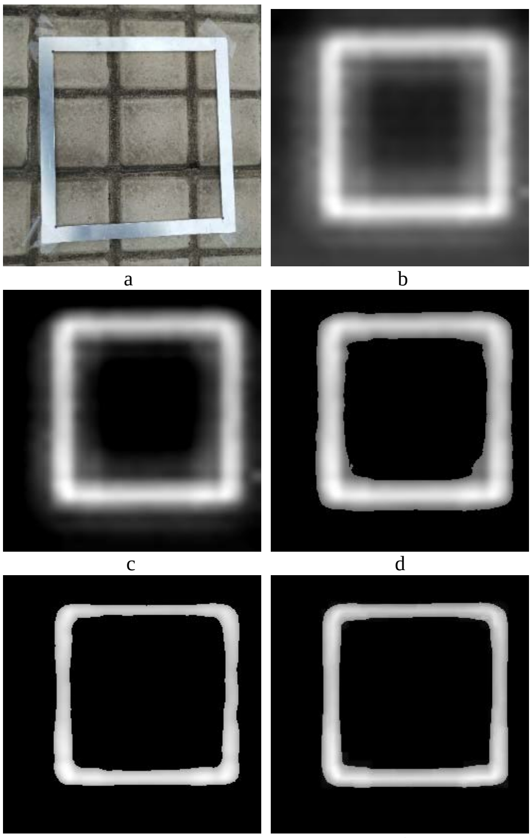

FIGURE II. EXPERIMENTAL RESULTS OF METAL TARGET

a. OPTICAL IMAGE OF THE METAL TARGET

b. THE MMW RADIOMETRIC IMAGE BEFORE PROCESSING

c. IMAGE AFTER PRE-PROCESSING

d. RESULT OF FIRST OTSU SEGMENTATION

e. RESULT OF SECOND OTSU SEGMENTATION

f. THE FINAL RESUL

V. CONCLUSION

For the MMW radiometric image with blurred edge and transition band, the traditional Otsu segmentation method usually doesn't work well. In this paper, to help study the target detected by millimeter wave radiometer, a relatively simple improved threshold selection method is proposed for the segmentation of MMW radiometric image to get the part of interested target. The method first uses the global information and Otsu method twice to get a small region which should contain the edge of the target. Then the threshold for final segmentation is obtained by applying the maximum entropy method to this local region. With the consideration of both global information and local information, the improved method takes use of the advantage of Otsu thresholding method and maximum entropy method. The experimental result of the metal target shows that the proposed method is superior to the traditional method in finding the right threshold to segment and it's simpler in calculation. In spite of this, with respect to the accuracy of segmentation result and the target segmentation of complex image, more work is needed.

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