Infrared Image Segmentation Based on Otsu and Genetic Algorithm

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Abstract—**The infrared image is formed by the thermal infrared rays of the targets and environment. As the targets radiate more heat, we can see they have larger grey-scale, locating in the top-end of histogram. According to this characteristic of infrared images, a new method for infrared image segmentation based on Otsu and genetic algorithm is proposed in this paper. First, covert the infrared image to grayscale image; Second, detect the image edge, and get the best threshold for image segmentation by Otsu and GA (Otsu-GA); Finally, Segment the image by the threshold, and contrast the results of two peaks and iteration. Experimental results show that the method effectively improved the quality of image segmentation.**

Keywords-Infrared Image Segmentation; Threshold; Otsu; Genetic Algorithm

I. INTRODUCTION

Infrared image segmentation is useful in many applications. From the segmentation results, it is possible to identify regions of interest and objects in the scene, which is very beneficial to the subsequent image analysis or annotation. The traditional methods of threshold segmentation are: based on threshold of pixel, based on threshold of regional property, and based on threshold of transitional region. However, due to the difficult nature of the problem, there are few automatic algorithms that can work well on a large variety of data [1-5].

As the targets radiate more heat, we can see they have larger grey-scale, locating in the top-end of histogram, because the infrared image is formed by the thermal infrared rays of the targets and environment. According to this characteristic of infrared images, a new method for infrared image segmentation based on Otsu and genetic algorithm is proposed in this paper.

II. CHARACTERISTICS OF INFRARED IMAGE

Infrared images have the following characteristics: (1) Infrared thermal image characterize the temperature distribution of scene, it is are grayscale image, not color or shading image (three-dimensional sense), so for the human eye, it is low resolution and resolution; (2) As heat balance, long-wavelength, long transmission distance, atmospheric attenuation and other reasons, infrared images gets the features of strong spatial correlation, low contrast, the visual effect is unclear; (3) The detection ability of thermal imaging systems is bad and it's spatial resolution lower than visible light CCD array, makes the clarity of infrared image lower than visible light image; (4) the random interference of external environment, and thermal imaging system is imperfect, they can to bring a wide range of infrared image noise, such as thermal noise, shot noise, photon noise. The complex distribution noise makes the signal to noise ratio of infrared image is lower than ordinary television picture; (5) Since the inconsistency of response characteristics for infrared detector unit, results the non-uniformity of the infrared image, reflected in image as fixed pattern noise and distortion.

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III. OTSU ALGORITHM

Otsu method is proposed in 1978 by Otsu [6], because its calculation is simple, stable and effective, it has been widely used. The basic idea: select the optimal threshold t, it should be making the best separation between different classes. First, Histogram has been calculated based on the probability of segment eigenvalue, and according to the threshold value t, the segment eigenvalue will be divided into two separate features, then find the variance of each type of within-class and between-class, choose the threshold t, it makes the between-class variance is the largest, and the within-class variance is smallest, as the best threshold. Specific steps are as follows:

Let the original gray image gray level is L, the gray level of pixel i, the number n_i, the total number of pixels of the image:

$$N = n_0 + n_1 + \ldots + n_{L-1} \tag{1}$$

Threshold t by all the pixels can be divided into two categories: C0= (0, 1, 2, ..., t) and C1= (t +1, t + 2, ..., L-1), while the C0 and C1 class probability of class w, and all kinds of mean μ is given by the following:

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$$w_0 = p_r(C_0) = \sum_{i=0}^{t} P_i = w(t) \tag{2}$$

$$w_1 = p_r(C_1) = \sum_{i=t+1}^{L-1} P_i = 1 - w(t) \tag{3}$$

$$\mu_0 = \sum_{i=0}^{t} iP_i \Big/ w_0 = \mu(t)/w(t) \tag{4}$$

$$\mu_1 = \sum_{i=t+1}^{L-1} iP_i \Big/ w_1 = \frac{\mu_L(t) - \mu_t(t)}{1 - w(t)} \tag{5}$$

Where: $\mu(t) = \sum_{i=0}^{t} iP_i$, $\mu_L(t) = \sum_{i=0}^{L-1} iP_i$, $P_i = n_1/N$, $\sum_{i=0}^{L-1} p_i = 1$.

Difficult to conclude that for any t value, the following formula can be established:

$$w_0\mu_0 + w_1\mu_1 = \mu_T \qquad w_0 + w_1 = 1 \tag{6}$$

C0 and C1 class variance by the following formula:

$$\sigma_0^2 = \sum_{i=t+1}^{L-1} (i - \mu_1)^2 p_i \Big/ w_1 \tag{7}$$

$$\sigma_1^2 = \sum_{i=0}^{t} (i - \mu_0)^2 p_i \Big/ w_0 \tag{8}$$

Define class variance σ_W , between-class variance σ_B , σ_T population variance is:

$$\sigma_W = w_0\mu_0^2 + w_1\mu_1^2 \tag{9}$$

$$\sigma_B = w_0(\mu_0 - \mu_T)^2 + w_1(\mu_1 - \mu_T)^2 \tag{10}$$

$$\sigma_T^2 = \sigma_W^2 + \sigma_B^2 \tag{11}$$

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$$\eta(t)^2 = \sigma_W^2 + \sigma_B^2) \tag{12}$$

The optimal threshold T_{OP} can choose to:

$$T_{OP} = \max(\eta(t)) \tag{13}$$

In image processing, the original image segmentation methods inevitably produce errors, these errors will affect the image processing and recognition results. How to minimize these errors is to make practical use of computer vision to achieve an important requirement. Genetic algorithm and its inherent parallelism is not easy to fall into local optimum characteristics make it very suitable for large-scale optimization search space, therefore, has been widely used in image processing. Image segmentation is a complex parameter space to find the optimal segmentation parameters of the problem. However, genetic algorithm can effectively find the global optimal parameter value space for image segmentation.

IV. OTSU COMBINED WITH GENETIC ALGORITHM (OTSU-GA)

Otsu solving process is in the solution space to find an optimal solution, making the maximum between-class variance. In order to improve general Otsu method, genetic algorithm, find the process of finding the optimal solution to improve.

1) Convert the infrared image into grayscale image;

2) Detect the image edge, and get the best threshold for image segmentation by Otsu and GA;

The steps of Otsu method combined with genetic algorithm showing in Fig. 1.

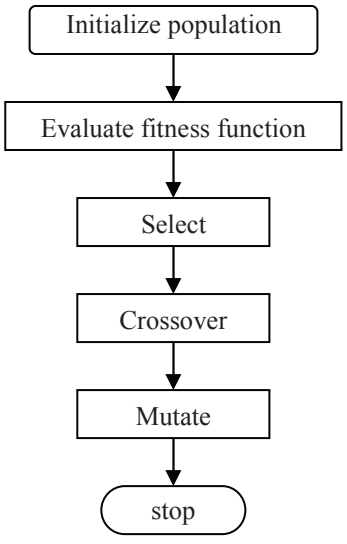

Figure 1. The flowchart of Otsu based on genetic algorithm

a) Initialize population and the code: create the initial population, from 0 to 255 with equal probability of randomly generated initial population. Usually, the initial population size is not too large. Generate 40 individuals with same probability randomly - as the first optimization of the initial population, and then perform the change of binary code and real value.

b) Evaluate fitness function: using the formula (15) to calculate the individual fitness value:

$$P_1 = S_1,\ P_2 = S_2 \tag{14}$$

$$F(k) = I * J(P_1 - P_2) * (P_1 - P_2)/128 * 256 \tag{15}$$

Where, $F(k)$ is the fitness function, and I is the number of target image pixels, J is the number of background image pixels; S_1 is sum of target image pixels and, S_2 is the sum of background image pixels.

c) Select: the need to set the gap of selection process, it means that not the entire population replicated fully.

d) Crossover: two individuals are selected in current population and cross-operation is done by each set crossover probability to generate a new population.

e) Mutate: according to the mutation probability, select each line of current population as an individual, and mutate each element corresponds to the mutation probability to form a new generation.

f) Stop: the program select a specific algebra (50 is selected in this paper) as the determine conditions of optimization loop stops. Determine whether the conditions to meet, if not, places the new group as the first generation, go to step (3), otherwise, select the individual with largest fitness as the best results, and it is the best threshold to segment the image.

3) Use the best threshold gotten from step 2) to segment the image.

V. EXPERIMENTAL RESULTS AND CONCLUSION

Three infrared images are chosen for the experiment. See Fig. 2 (a).

By the grayscale image of the infrared images obtained after contrast and edge-side: Set the number of initial population $N = 40, and\ P_c = 0.9$, the maximum number of iterations $G = 50$.After 50 times iteration optimizations, find the optimal threshold M=162, the segmentation results show in Fig. 2

If the target and background have a greater contrast in infrared image, the two peaks method can more accurately detect the target.

From the above segmentation results can be seen that iterative method can be more accurately segmented infrared images. Segmentation result shows the different regions have the same region value. Because the segmentation done by threshold only considers the value of the pixel itself, does not consider the spatial location of pixels. Therefore, the pixel assigned to the same type by the value pixels may belong to different connected region. Then some of the scenes often require a priori knowledge to further define the target area.

The Otsu segmentation combined with genetic algorithm is better than the pixel value thresholding method (two peaks method, iterative method), and other regional segmentation method. And the Otsu –GA method need little priori information of image for segmentation, the whole process has a high degree of automation, and for those whose histogram is not bimodal distribution, the algorithm can still treatment well, which expands the flexibility of the algorithm in practice.

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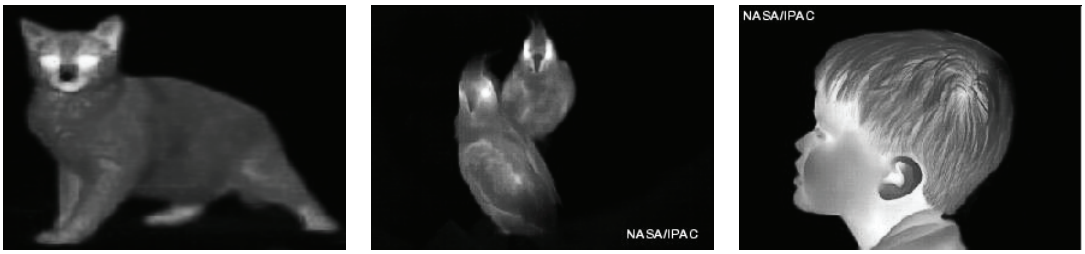
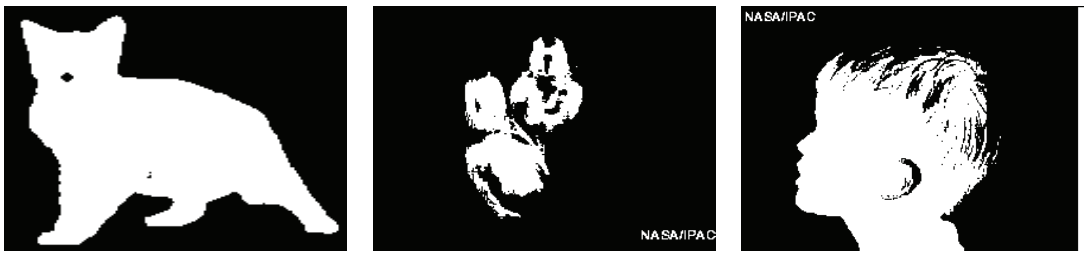


(a) The Infrared thermal images

(b) Result of two peaks



(c) Result of iteration

(d) Result of Otsu-GA

Figure 2. Results by various segment algorithms