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The Study on An Application of Otsu Method in Canny Operator

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***Abstract*—Canny algorithm can be used in extracting the object's contour clearly by setting the appropriate parameters. The Otsu algorithm can calculate the high threshold value which is significant to the Canny algorithm, and then this threshold value can be used in the Canny algorithm to detect the object's edge. From the exprimental result, the Otsu algorithm can be applied in choosing the threshold value which can be used in Canny algorithm, and this method improves the effect of extracting the edge of the Canny algorithm, and achieves the expect result finally.**

***Index Terms*—image segmentation; Otsu; Canny; threshold; edge detection**

I. Introduction

Auto-select threshold value is a difficulty and hot research field which is well known in image processing field. At present, there are dozens kinds of methods in selecting threshold value, and in fact the ones which is widely used are as follows: histogram trough method, Otsu method, maximum entropy method, vector retention method, graded statistics method and so on [1][2][3]. But there isn't a generic method and an objective standard to judge that whether it is successful in image segmentation field.

Otsu method [4] had been proposed in 1979, and it is deduced by least square(LS) method based on gray histogram. As we all known, this method not only has the best threshold value in the statistical sense, but also it is the most stable method in the image threshold segmentation at present. This paper has proposed a method that it confirms a best threshold value through Otsu method which can be regard as the high threshold value of Canny operator, and then extracts the image edge by the Canny operator. The experimental results indicates that the method which has proposed is reliable and practicable.

II. Canny Operator Theory

Canny has proposed a new method of edge detecting [5][6], which is the best one to step-type edge which is influenced by white noise. We know that Canny edge detector is formed by first-order derivative of Gaussian function. Gaussian function is circular symmetry, so Canny operator is symmetry on edge, and dissymmetry on vertical edge's direction [7]. Firstly, Canny operator processes the image smoothly through Gaussian convolution, and obtains the gradient image through differential operation to the image which is processed via Gaussian convolution; secondly, using the "non-maximum suppression" algorithm to find the possible edge points; finally, using the double-threshold value to find the image's edge points, and then obtain the image edge with only one pixel wide.

Suppose the two-dimensional Gaussian function is:

$$G(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right) \tag{1}$$

In this equation, σ is a distribution parameter of Gaussian function used for controlling to process a image smoothly. Making use of Gaussian function's separability, the two filtration convolution templates of ∇G can be decomposed to two one-dimension range filters:

$$\frac{\partial G}{\partial x} = kx \exp\left(-\frac{x^2}{2\sigma^2}\right) \exp\left(-\frac{y^2}{2\sigma^2}\right) = h_1(x) h_2(y) \tag{2}$$

$$\frac{\partial G}{\partial y} = ky \exp\left(-\frac{y^2}{2\sigma^2}\right) \exp\left(-\frac{x^2}{2\sigma^2}\right) = h_1(y) h_2(x) \tag{3}$$

In above equations:

$$h_1(x) = \sqrt{k}\, x \exp\left(-\frac{x^2}{2\sigma^2}\right)$$

$$h_1(y) = \sqrt{k}\, y \exp\left(-\frac{y^2}{2\sigma^2}\right)$$

$$h_2(x) = \sqrt{k} \exp\left(-\frac{x^2}{2\sigma^2}\right)$$

$$h_2(y) = \sqrt{k} \exp\left(-\frac{y^2}{2\sigma^2}\right)$$

$h_1(x) = xh_2(x)$, $h_1(y) = yh_2(y)$. k is constant.

Then, after convoluting the image $f(x, y)$ and the Eq.(2) and Eq.(3) respectively, it can obtain $M_x = \frac{\partial G}{\partial x} * f(x, y)$, $M_y = \frac{\partial G}{\partial y} * f(x, y)$.

Command: $T(i, j) = \sqrt{M_x^2(i, j) + M_y^2(i, j)}$

$$\theta(i, j) = \arctan\left[\frac{M_y(i, j)}{M_x(i, j)}\right] \tag{4}$$

Chinese National Natural Science Foundation: Research of dynamics space of macro-sized for rapid detection method based on symbols M array.

To follow, the $T(i, j)$ reflects edge intension at the point (i, j) and $\theta(i, j)$ reflects the normal vector at the point (i, j) in a image.

In summary, the detailed algorithm step of Canny operator as follows:

(1)、Smoothing image using Gaussian filtration (wipe off noise);

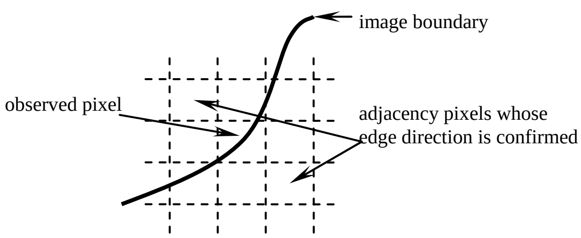
(2)、Obtaining a image's gradient intensity and direction using first-order differential coefficient to filtrate the image;

(3)、"non-maximum suppression"

- According to adjacent, the edge will be quantized to 4 directions and described in Fig.1(a);
- Aiming at every pixel whose value is non-zero, two adjacent pixels which is confirmed by edge direction are surveyed and described in Fig.1(b);
- If the two adjacent pixels' value is both greater than the current pixel's value, they will be marked and deleted.
- While all the pixels are surveyed, the algorithm will scan the image again and all the marked pixels' value will be replaced by gray value zero.

4	3	2
1	●	1
2	3	4

(a) 4-direction of pixel edge



(b) Observed pixel and its edge pixels position

Figure 1. Non-maximum suppression: adjacency pixels relationship

- Aiming at the gradient, the algorithm gets two threshold values namely Th_1 and Th_2, whose relationship is $Th_1 = 0.5 \times Th_2$ usually. We can set all the gray value which is lower than Th_1 in original image to zero and define it as image A, and similarly set the gray value which is lower than Th_2 in original image to zero and define it as image B.
- Edge connection.
- The algorithm will scan the image B until to meet the first non-zero pixel point S, then track the contour line which begins at point S to the destination point T.
- Observing the 8-domain of point T' in image A which is correspond with point T in image B. If there is non-zero value pixel P' in the 8-domain of point T', then it will be include into image B, namely it as point P. Later on, the algorithm will repeat the first step until there is no such point T' or T in image A or B respectively.
- When it completes the connection of contour line which includes the point S, the algorithm marks it accessed, and then return to the first step to find another contour line. The algorithm will repeat the first three step while find the new contour line in image B.

Above all, the Canny edge detection has been finished.

III. OTSU METHOD PRESENTATION

It is universally acknowledged that the Otsu is the best method of choosing threshold value automatically which is proposed in 1979 [4]. Its basic principle is to split the image's pixels into two classes, and confirms the best threshold value through the variance maximum value between the two classes[8][9][10].

Supposed that $G = [0, L-1]$ is the range of grayscale of image $f(x, y)$ and P_i is the probability of every grayscale, and the threshold value t has splitted the image in two classes which are $C_0 = [0, t]$ and $C_1 = [t+1, L-1]$. The two classes' probability are $\alpha_0 = \sum_{i=0}^{t} p_i$ and $\alpha_1 = 1 - \alpha_0$ respectively. The average gray value of the two classes are $\mu_0 = \sum_{i=0}^{t} \frac{iP_i}{\alpha_0} = \frac{\mu_t}{\alpha_0}$ and $\mu_1 = \sum_{i=t+1}^{L-1} \frac{iP_i}{\alpha_1} = \frac{\mu - \mu_t}{1 - \alpha_0}$ respectively, therein $\mu = \sum_{i=0}^{L-1} iP_i$, $\mu_t = \sum_{i=0}^{t} iP_i$. The criterion function has been defined as variance between the two classes, expressed as:

$$\eta^2(t) = \alpha_0(\mu_0 - \mu)^2 + \alpha_1(\mu_1 - \mu)^2 = \alpha_0\alpha_1(\mu_0 - \mu_1)^2 \qquad (5)$$

Calculating the Eq. (5) above, we can obtain the maximum t which is the threshold value namely, and mark it t^*.

IV. THRESHOLD PARAMETER SETTING

The three parameters which are Gaussian filtration convolution kernel which is used for smoothing image and the two threshold values Th_1 and Th_2 which are used in tracking decide the capability of Canny operator. Through analyzing, the algorithm can decrease the noise while increasing σ in the detecting process, but at the same time the result image will lost some details and become indistinct; the algorithm can wipe off most of the noise while increasing the value of Th_2, but meanwhile some edge information which is very useful will be lost. The threshold values Th_1 is the key of controlling effect of edge detecting. Along with the Th_1 decreasing, more and more edge information will be reserved; but by contrary, the edge's characteristic will become less and less, and the edge will be broke-away.

In order to let the Th_2 of Canny operator has a self-adapting processing, we can regard the threshold values which can be calculated via Eq. (5) as Th_2. So the three parameters of Canny is as follows:

① $\sigma = 2$;

② $Th_2 = t^*$;

③ $Th_1 = 0.5Th_2$.

So above all, in fact the double-threshold value in Canny operator is a threshold value too, and we can confirm that it is practical to calculate the Th_2 using Otsu algorithm through analyzing the choice principium of Th_1 and Th_2 and graded histogram.

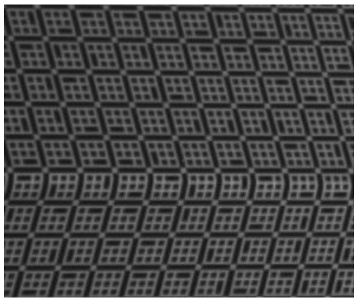
V. RESULT

In this paper, the image which is used in this algorithm is gained by picturing the template which is projected to the object via CCD, and the template is formed by the symbols via pseudorandom method which is selected by ourselves, example for Table I, and the symbols has been connected by small points namely bridge point, example for Fig 2(a). This image's histogram has the characteristic of two-extremum. Canny algorithm can use the threshold value which is gained by the Otsu method automatically to obtain the image's contour line。

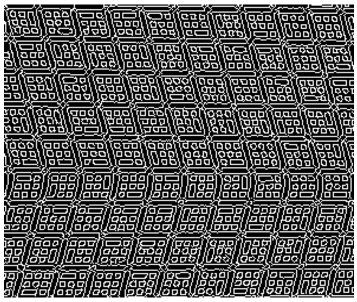
T ABLE I. SYMBOLS LIST

Index	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
symbols									

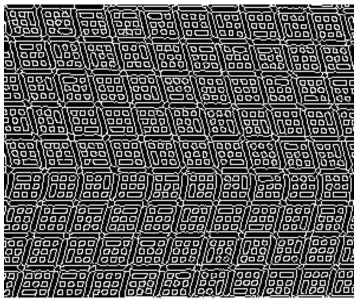
Then, this paper has compared the result of contour edge which is calculated by normal Canny operator with the one which is calculate by this paper's method which has improved. Compared Fig.2(b) with Fig.2(c), we can point out that the edge fragmentation phenomena is badly and much edge is not detected while using the normal Canny operator, especially the bridge points whose function is to connect the symbols; but the improved



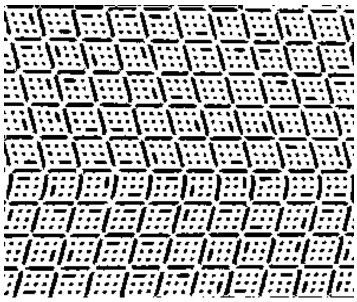
(a) original image



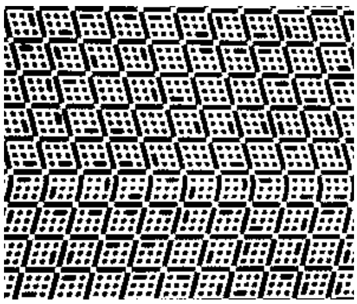
(b) extracting contour result through normal Canny method



(c) extracting contour result through improved method



(d) after filling symbols of picture (c)



(e) result of threshold segmentation using Otsu method

Figure 2. Experimental Result

algorithm can not only detect the important edge contour but also make the edge contour continuity based on characteristic of symbol's shape and restrain produce the inveracious edge. After having extracted the symbols' contour, we should fill the symbols to make them become solid ones, example for fig.2(d). Compared Fig.2(d) with Fig.2(e), there is no break-away phenomena of symbols in Fig.2(d); meanwhile few symbols' contour is broken which is displayed in Fig.2(e). The contour break of symbols is the fatal phenomena to our method, because the next step is to extract centerline of every symbol and then recognize every symbol via chain code. So we can conclude that the improved threshold fragmenting method is much better.

VI. CONCLUSIONS

This paper has described the principium of Canny operator and Otsu threshold fragmenting method, and proposed to calculate the high threshold value which is significant to Canny operator through the method of variance maximum between classes. From the exprimental result, the algorithm which has proposed in this paper has improved the effect of edge extraction. And it can be applied to the image whose histogram presents the characteristic of two-extremum, so we can conclude that this algorithm not only can be applied to this experiment's image, but also can be applied to the image which has same characteristic.

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