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Edge Detection Based on Improved Sobel Operator

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***Abstract*-Sobel algorithm is an important method of image edge detection. Comparing the Sobel operator with several other edge detection operators used frequently and making a further study on the classical Sobel operator, the advantages of Sobel operator are its fast detection speed, meanwhile , it has an effect on smoothing and suppressing noise. Also, Sobel operator has a good effect on edge detection. Although Sobel operator has advantages in many aspects, it exists some problems: the Sobel operator is a kind of edge detection in horizontal and vertical direction, so it neglects edge points in other directions. It can not achieve a true detection for the points on image edge. In this paper, the algorithm is based on the Sobel operator, an increase of 45 degrees and 135 degrees 2 direction template, while the main edge of the oblique, re-assigned the weight of the operator template. At the same time, in order to achieve an effect of detection, binarization method is used to make an edge thinning for detected image. According to simulation experiments, they show this method is simple and feasible, and the detective result is more concrete and abundant than traditional Sobel edge detection. Some problems are improved, such as traditional Sobel edge is rough and detection is incomplete.**

Keywords-sobel operator; binarization; edge detection; edge thinning

I. INTRODUCTION

In digital image processing, edge feature is one of the important features of the image, and it is an important part of image processing, pattern recognition and computer vision. The results of image edge detection affect the further image processing and pattern recognition directly. In recent decades, the image edge detection technology has become an important research topic in digital image processing technology. With the development of science and technology, researchers have proposed some methods for image edge detection and evaluation of edge detection. At the same time, these edge detection techniques are applied to the field of computer vision and pattern recognition, which makes the application of edge detection technology more and more widely [1]. Over the years, image segmentation has been attracting more and more attention. Thousands of segmentation algorithms have been put forward. They can be divided into bit threshold method, edge detection method and regional growth method [2]. Edge detection method includes: first order differential edge detection operator includes Roberts operator, Prewitt operator, LOG operator and Sobel operator.In contrast, in many respects, Sobel operators are superior to others. However, the classical Sobel operator also has some problems. The Sobel operator is sensitive only to the vertical direction and the horizontal direction. However, the image information is not limited to the horizontal and vertical direction; it can make part of the image information lose. In this paper, a new improved operator is proposed based on the sobel operator. On the traditional Sobel operator, the 45 degrees and 135 degrees 2 direction templates are added to realize multi- directional image acquisition. Then calculate the threshold by using the Otsu method and refine the detected rough edges by using binarization method to achieve the results of image edge detection. Edge detection effect can be achieved better by using Matlab simulation method.

A comparison table of various operators is shown in Table 1:

II. THE COMPARISON OF SEVERAL TRADITIONAL OPERATORS

- Roberts operator: did not pass smooth calculation, so it is more sensitive to the noise.
- Prewitt operator and Sobel operator: edge extraction effect is almost the same. Prewitt operator is an average filter, Sobel operator is a weighted average filter; they have better detection effect on images which have low gray level noise, but the detection effect is not obvious.
- LOG operator: detecting edge by using two order derivatives zero crossing edge method. Smoothing effect is more significant, removing effect of noise is better, but the loss of image details is larger, the edge precision is lower. So there is a contradiction between positioning edge accuracy and eliminating noise level.

III. THE PRINCIPLES OF THE TRADITIONAL SOBEL OPERATOR

Sobel cross-differential operator, because of its role in the template is small, the relative calculation is also small, thus the image details of the contour can be obtained. But because the template size is even, the pending pixel cannot be placed in the center position of the template, or the results will have half pixel fault. Sobel differential operator is a directional differential operator in a basis of odd size template. The expressions of formula as follow (3.1), (3.2):

$$\begin{aligned} G_x(i,j) = {} & f[i-1,j+1] + 2\times f[i,j+1] \\ & + f[i+1,j+1] - f[i-1,j-1] \\ & -2\times f[i,j-1] - f[i+1,j-1] \end{aligned} \tag{3.1}$$

$$\begin{aligned} G_y(i,j) = {} & f[i+1,j-1] + 2\times f[i+1,j] \\ & + f[i+1,j+1] - f[i-1,j-1] \\ & -2\times f[i-1,j] - f[i-1,j+1] \end{aligned} \tag{3.2}$$

The convolution template of the Sobel operator is expressed as the formula (3.3) and (3.4):

$$G_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \tag{3.3}$$

$$G_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{3.4}$$

The calculating steps of Sobel operator: first, the edge detection image is divided into matrix form (3.5):

$$A = \begin{bmatrix} f_1(x-1,y-1) & f_1(x-1,y) & f_1(x-1,y+1) \\ f_1(x,y-1) & f_1(x,y) & f_1(x,y+1) \\ f_1(x+1,y-1) & f_1(x+1,y) & f_1(x+1,y+1) \end{bmatrix} \tag{3.5}$$

Multiply horizontal direction by vertical direction of the template and then multiply the vertical direction by horizontal direction of the template, Fx=Gx.*A, Fx=Gy.*A. gradient size calculation, as shown in the formula (3.6):

$$G = \sqrt{\left(G_x^2 + G_y^2\right)} \tag{3.6}$$

The formula for calculating the gradient direction is shown in the formula (3.7):

$$\theta = \arctan\left(\frac{G_y}{G_x}\right) \tag{3.7}$$

When θ is equal to zero, there is a vertical edge on behalf of the image, the left side is dark er than right side.

The Sobel operator introduced the weighted local average, it can not only affect the image edge detection but also suppress noise further, but the edge is wider. The basis idea of Sobel operator algorithm: because the edge of the image is located at the place in which the brightness changes significantly, therefore in the neighborhood of the pixel gray value of pixels exceeds a set threshold depending on the specific steps for the edge [3]. The specific steps of Sobel operator algorithm are as follows [4]:

- Moving the horizontal and vertical direction templates from left to right, from top to bottom, and moving from one pixel to another, and the center of the template corresponds to the corresponding pixels in the image.
- Multiplying the coefficients in the template with the corresponding pixel values in the image.
- The gradient value is calculated as a new gray value by using 2 convolution values.
- Select the appropriate threshold TH, if the new pixel value ≥ TH, the pixel points can be regarded as image edge points.

IV. THE IMPROVEMENT OF THE TRADITIONAL SOBEL OPERATOR

Adding 45 degrees and 135 degrees direction template in a basis of the traditional Sobel operator, the direction template are changed into four directions: the horizontal and vertical direction and 45 degrees and 135 degrees direction. It improved the weights of new template in the direction of oblique edge. Specific details are as follows:

According to the calculation of the four template

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

horizontal direction 45 degree direction

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$$

vertical direction 135 degree direction

directions and the calculating an image point by point, the maximum value is regarded as the pixel gray values. According to the threshold setting, edge point is determined. The template maximum value corresponding to represents the direction of edge direction of the pixel.

A. Edge Thinning Processing

The edge of the image contains a lot of image information, by the direction of the traditional Sobel operator improvement, only the gradient information. The edge appears where the gradient value is large. To extract the edge of the image, a threshold must be set and then binarized. In general, the gradient image obtained by the gradient operator has a thicker edge. If the gradient image threshold is set directly to binarization, it is difficult to find a suitable threshold, so that the detected edge can meet the requirements. This is not easy to edge processing and edge feature extraction and other post-processing.Therefore, it is necessary to refine the edge of the gradient before

binarizing the image gradient [5].

The refinement process is to find the pixel (a, b) Max a maximum value in the neighborhood of (a, b), and set the threshold locally according to Max (a, b). According to the gradient value and the choice of the threshold, so that we can achieve the refinement of gradient map, with the body is shown in formula (4.1):

$$edge(a,b) = \begin{cases} Max(a,b) & grade(a,b) > a * Max(a,b) \\ 0 & \text{other} \end{cases} \quad (4.1)$$

Type: grade (a, b) pixels (a, b) corresponding to the gradient values, Max (a, b) is (a, b) 8 neighborhood maximum gradient value, a is the control factor (0<a<1), through the different value of A we can achieve the width K. Experimental results show that when the value of a in the 0.7-0.9, the edge width of two value is the idealist. It can not only achieve the purpose of edge thinning, but also helpful to the threshold selection on the image binarization.

B. Edge Two Value Based on Otsu Method

The selection of gradient image binarization is vital to image edge detection, it is also considered as a difficulty in edge detection. This paper adopts the Otsu method, a method about making class variance maximally determine threshold automatically. This method is simple, fast, often used in threshold selection. The way of graythresh calculating threshold in the MATLAB is Otsu method. The specific steps are as follows [6]:

- Given an initial threshold TH, the image is divided into C1 and C2 two categories.
- Calculate the gray mean value of u1 and u2, and the average u gray value of the image.
- Calculate the probability of p1 and p2.

$$p_1 = \sum_{i=0}^{TH} p_i \quad (4.2)$$

$$p_2 = 1 - p_1 \quad (4.3)$$

- Computation between class variance δ_b^2.

$$\delta_b^2 = p_1 * (\mu_1 - \mu)^2 + p_2 * (\mu_2 - \mu)^2 \quad (4.4)$$

- Select the best threshold TH1, and according to the threshold, making the image divided into C1 and C2. By using the Otsu method in MATLAB, the threshold value of the graythresh can be obtained. Then the threshold value is used to carry out the two value of the thinning image.

V. EXPERIMENTAL RESULTS AND SIMULATION

When we do simulation experiments in the MATLAB2010 experimental platform, the first is to take a separate Sobel operator for image edge detection, and then use the algorithm for image edge detection; make a comparison between them, Figure 1and4 shows the original, the sobel edge detection is shown in Fig2and5, in this paper edge detection is shown in Fig 3 and 6:

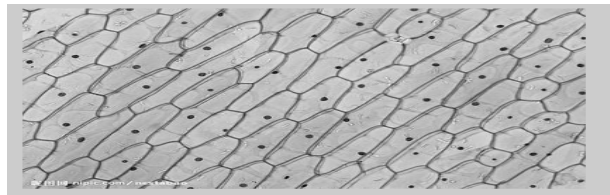

Figure 1.

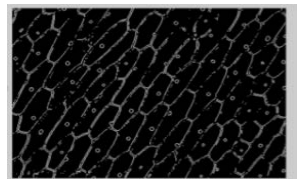

Figure 2.

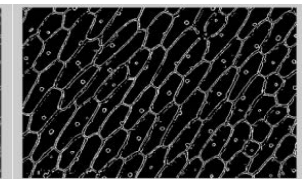

Figure 3.

Figure 4.

Figure 5.

Figure 6.

After the detection of the image 45 degrees and 135 degrees directional template, it fully verified the previous statement. The two directions have edge information of images, and then make a comparison among the detection of the four directions: two direction, vertical direction and horizontal direction. And found that the direct application of Sobel operator for edge detection contains more original image edge information than the information of single

direction edge detection, but there still exists some disadvantages, such as rough edge detection, inaccurate detection. Compared with the traditional Sobel algorithm, it displayed more information of original image; the edge is more specific and contains more information. Before the processing of gradient image binarization, the algorithm made a refinement and combined with the oblique edge direction information of gradient image thinning after the binarization processing. The experimental results show that this algorithm overcomes the disadvantages of traditional Sobel operator edge detection, such as rough edge detection, discontinuity and other defects; it achieves a better edge detection effect.

VI. CONCLUDING REMARKS

According to comparisons among all kinds of first order operators, we choose the traditional Sobel operator ang make a better improvement. From theory and experiment, it proved that this algorithm is better than the traditional Sobel operator in image edge detection, and achieves the specific accurate detection and reduces the loss of edge. The experiments show that the method provided in this paper is feasible.

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TABLE I. TABLE

function	Roberts	Prewitt	LOG	Sobel	Algorithm in this paper
Missing edge detection	More	More	More	less	very little
Time consumption of the algorithm	1s	1s	1s	1s	1.2s
Ability to resist noise	Very weak	common	Very weak	Strong	Very Strong