An improved CANNY edge detection algorithm

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***Abstract*—CANNY arithmetic operator has been proved to have good detective effect in the common usage of edge detection. However, CANNY operator also has certain deficiencies. Based on the analysis of the traditional CANNY algorithm, an improved canny algorithm is proposed in this paper. In the algorithm, self-adaptive filter is used to replace the Gaussian filter, morphological thinning is adopted to thin the edge and morphological operator is used to achieved the refining treatment of edge points detection and the single pixel level edge. The results of experiment show the improved CANNY algorithm is reasonable.**

Keywords- ***edge detection; canny algorithm; adaptive filter***

I. INTRODUCTION

Image edge is a fundamental feature of image, which contains abundant internal information, such as direction, step characteristics, shape and etc, so it has been widely used in image segmentation, image categorization, image registration, and pattern recognition [1]. The edge mostly exists between object and object, object and background, area and area. Edge detection is considered as an important research of this domain and a huge amount of researches has been conducted, typical the first order differential operator such as Roberts operator, Prewitt operator, and Sobel operator and second order differential operator such as Laplace operator and LOG operator.

In 1986, Canny proposed the edge detection operator based on optimization algorithm and the three strictest criteria for edge detection so far. The relatively simple algorithm makes the whole process be efficiently executed and has been widely used [2]. But the traditional CANNY operator has the defect that being vulnerable to various noise disturbances, so there are certain limitations of its concrete application. For these above problems, various researches have been carried out and many improvement measures have been proposed. Thorough deeply researching previous works, this paper proposes an improved algorithm, in which self-adaptive filter is used to replace the Gaussian filter and morphological thinning is adopted to thin the edge, the improved algorithm improves the precision of the detection.

II. THE PRINCIPLE OF TRADITION CANNY ALGORITHM

A. The principle of tradition CANNY algorithm

The canny algorithm consists of three criterion of the edge detection algorithm.

1) The criterion of SNR

The larger of the SNR, the higher quality of the detection edge. The SNR is defined as follow:

$$SNR = \frac{\left|\int_{-W}^{+W} G(-x)h(x)dx\right|}{\sigma\sqrt{\int_{-W}^{+W} h^2(x)dx}} \qquad (1)$$

Where, the $G(x)$ represents the edge function, $h(x)$ represents the impulse response of the filter of width is W. σ represents the mean square deviation of the Gaussian noise [3].

2) The criterion of positioning accuracy

The positioning accuracy of the edge is defined as follow:

$$L = \frac{\left|\int_{-W}^{+W} G'(-x)h'(-x)dx\right|}{\sigma\sqrt{\int_{-W}^{+W} h'^2(x)dx}} \qquad (2)$$

Where the $G'(x)$ and $h'(x)$ respectively is the derivative of the $G(x)$ and $h(x)$, the larger of the positioning accuracy, the result is better.

3) The criterion of the singleness edge response

To ensure the edge only have one response, the average distance ($D(f')$) of the zero-crossing point of the derivative of the impulse response of the edge detection algorithm. The $D(f')$ should meet the follow formula:

$$D(f') = \pi\left\{\frac{\int_{-\infty}^{+\infty} h'^2(x)dx}{\int_{-W}^{+W} h''^2(x)dx}\right\}^{\frac{1}{2}} \qquad (3)$$

Where, $h''(x)$ is the second derivative of $h(x)$.

B. The detecting process of the CANNY algorithm

The detecting process of the CANNY algorithm consists of the following steps [4].

1) Use the Gaussian filter smoothing image to restrain noise.

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2) Use the finite difference of the first order partial derivative for calculating the gradient magnitude $M(x,y)$ and the gradient direction $H(x,y)$ of the image. $M(x,y)$ Is defined as follow:

$$M(x,y)=\sqrt{E_x(x,y)^2+E_y(x,y)^2} \quad (4)$$

The $H(x,y)$ is defined as follow:

$$H(x,y)=\arctan(Ey(x,y)/Ex(x,y)) \quad (5)$$

Where, Ex and Ey is the result what the image being effected by the filter along the row-column direction.

3) Do non-maximum suppression for the gradient magnitude.

4) Dual-threshold algorithm is adopted to detect and connect edges.

C. The main defects of the tradition canny algorithm are as follows [5].

1) Use the Gaussian filter, when smooth the noise, some edge also be smoothed, so some edge is weakened. What make the detection result have some isolated edge and some false edge.

2) The Dual-threshold is difficult to determine, this will make lose some edge or can't removal the noise.

3) The result of the detection can't reach the single pixel grade, at some point; multi-point response will appear [6].

III. I MPROVED CANNY OPERATOR

A. The improved of the filter

As the edge and the noise both are high frequency signal. This paper proposes the adaptive filter instead the Gaussian filter, which can select the weight adaptively according the jump features of the gray values of the image, and at the same time, sharpening the edge of the image.

Supposing the weight of the adaptive filter is $w^k(m)$, the measurement of the jump features of the gray values of the image is $d(m)$, then, the function $f(d(m))$ is monotone. The larger change of the discontinuity of the gray value, the $w^k(m)$ should be set lower, contrarily, when the change is lower, the $w^k(m)$ should larger.

Define the two-dimensional image as $f(x,y)$:

$$G_x(x,y)=\frac{\partial f(x,y)}{\partial x}, \quad G_y(x,y)=\frac{\partial f(x,y)}{\partial y},$$

$$d(x)=\sqrt{(G_x(x,y))^2+(G_y(x,y))^2} \quad (6)$$

Define weight function

$$w(x,y)=\exp\left[-\frac{\sqrt{d(x,y)}}{2h^2}\right] \quad (7)$$

Where, h is the coefficient of the amplitude of the edge. According to the defining of above structure, the process of adaptive filter is described as following:

1) $k=1$, set the iteration n and the coefficient of the amplitude of the edge h.

2) Use the difference method calculate the gradient values $G_x(x,y)$ and $G_y(x,y)$.

$$G_x(x,y)=\frac{1}{2}[f(x+1,y)-f(x-1,y)],$$

$$G_y(x,y)=\frac{1}{2}[f(x,y+1)-f(x,y-1)]$$

3) Calculate the weight according to the formula (6) and (7).

4) Using the definition of adaptive filter

$$f(x,y)=\frac{1}{N}\sum_{i=-1}^{1}\sum_{j=-1}^{1}f(x+i,y+j)w(x+i,y+j)$$

To smooth the image, which

$$N=\sum_{i=-1}^{1}\sum_{j=-1}^{1}w(x+i,y+j)$$

5) When $k=n$, stop the iterative, otherwise, $k=k+1$, keep do the step 2.

The proposed adaptive filter, not only can smooth the noise, but also can make the edge enhanced, which solve the contradiction of smoothing the noise and weakening the edge.

B. The method of edge point detection and connect based on gradient direction

As the gradient magnitude can't proper define the lower edge and the noise, simultaneously, the edge also has the gradient direction except the gradient magnitude, the gradient direction of the edge has a fixed direction, but the noise's direction is non-fixing. Therefore, according to the difference of the edge and the noise, we can distinguish the edge and the noise.

1) The theory of the algorithm.

As the fig 1 shows, in the area of the 8-neighbor by the center of point 0, we define the line connecting of the each point and the center point is $Seg_t=\{(0,t)\,|\,t=1,...,8\}$. Obviously, when the center point and any point of the neighbor is at the same edge, the Seg_t is also at the edge.

Now we define Ang_t as the absolute value between the average gradient direction and the normal direction of the center point and each point at the area. As the gradient direction and the normal direction of the edge point is in the same direction, so, the Ang_t is smaller, if the Ang_t is less than T (a small value), we consider the point is edge point, but the noise points don't have the property.

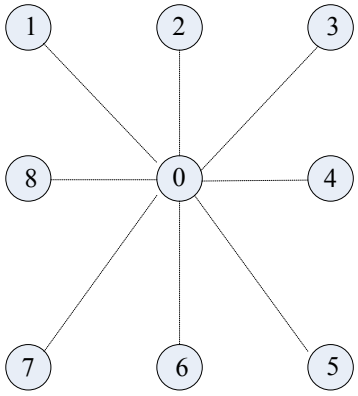


Fig 1 The 8-neighbor structure

2) The process of the algorithm

a) Scan the edge image, for the candidate point $N(i,j)$, to detection the 8-neighbor area, if there isn't other candidate point, go step 6.

b) According to the gradient direction to calculate the Ang_t of the $N(i,j)$ and the detection point, if Ang_t<T, go step 4.

c) Continuing to scan the points of the 8-neighbor area which aren't be marked, and calculate the Ang_t, if Ang_t<T, go step 4, other wise, go step 6.

d) Mark the center point $N(i,j)$ and all the points t_p which meet the Ang_t<T as edge point, and then connect the edge.

e) Detection the 8-neighbor area of t_p, if there are candidate points, mark them as edge points, until there are no points be marked, go to step 3.

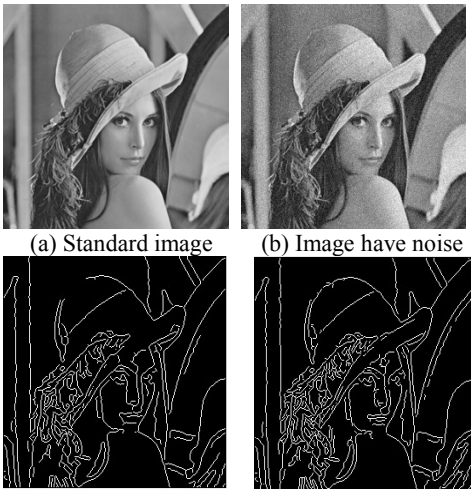
f) Continue to scan the image, finding new edge point, if the point isn't be marked, go step 1; otherwise, scan other points, until there isn't new point.

C. The thinning of the edge

The tradition canny algorithm can basically meet the vision requirement, but can't reach the single pixel, especially, the corner point often appear response of many-to-one. In order to implementation the single pixel, this paper use mathematical morphology to thin the detected edge, which is proposed in the literature [7].

IV. THE RESULT AND THE ANALYSIS

MATLAB is used to simulation the improved algorithm, first , add the adaptive filter and adopt the method of gradient direction to detect the edge, then use the mathematical morphology to thin the detected edge, the result is as follows



(a) Standard image (b) Image have noise

(c) Tradition operator (d) Improved operator

Fig 2 Experimental results

From the result of the detection, the improved operator have a better detection effect, compared with the image(c), the (d) obviously has been improved, pay attention to the breakpoints in top and edge of the hat. criterions are used to measure the result of the improved operator: the running time of the algorithm, 4-connectivity(A), 8- connectivity (B) and the ratio of B/A.

4-connectivity is expressed if there have some connect pixels at the area of its 4-connectivity, the same is to 8-connectivity. In general, the lower of the B/A, the better of the degree of the edge connection.

The table 1 shows the criterion of the two algorithms.

Table 1. The criterion of the two algorithms

	Time	A	B	B/A
Tradition algorithm	57	8263	843	0.1021
Improved algorithm	63	9027	897	0.0994

From the table 1, we can see that the improved algorithm achieves better effects of the edge detection, but it spends more time, which is the work we should do in next stage.

V. CONCLUSIONS

This paper introduced an improved canny algorithm, using the adaptive filter instead of the Gaussian filter, and proposed the gradient direction to detect the edge; finally, we adopt the mathematical morphology thinning to thin the edge. The result showed that the improved algorithm was better than the tradition algorithm. But, the improved

algorithm has the problem of heavy calculation, which needs to be further improved in next stage.

VI. REFERENCES

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