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A New Edge Detection Algorithm Based on Canny Idea

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Abstract. The traditional Canny algorithm has poor self-adaptability threshold, and it is more sensitive to noise. In order to overcome these drawbacks, this paper proposed a new edge detection method based on Canny algorithm. Firstly, the media filtering and filtering based on the method of Euclidean distance are adopted to process it; secondly using the Frei-chen algorithm to calculate gradient amplitude; finally, using the Otsu algorithm to calculate partial gradient amplitude operation to get images of thresholds value, then find the average of all thresholds that had been calculated, half of the average is high threshold value, and the half of the high threshold value is low threshold value. Experiment results show that this new method can effectively suppress noise disturbance, keep the edge information, and also improve the edge detection accuracy.

Key words: Edge Detection; Canny Operator; Media Filtering; Frei-Chen Operator; Otsu Operator.

INTRODUCTION

The edge of the image contains rich information, Edge detection algorithms are considered to be the main method of research [1]. The Canny edge detection algorithm is one of the most widely used in many computer vision and image analysis applications. However, there are some problems such as weak anti-noise ability and false edge [2].

The improved Canny algorithm is optimized from filtering and gradient amplitude, direction and so on. Such as morphological opening and closing operations instead of the traditional Gaussian filtering [3]; Robinson, Kirsch and other algorithms instead of Sobel algorithm to improve the ability to suppress noise [4,5]; Using Genetic algorithm, Iterative method and Otsu algorithm to select high and low threshold [6-8]. Use Otsu algorithm instead of manually to select the high and low thresholds. This method could consume less computation time and achieve the optimal value.

However, the Otsu algorithm is used to select the high and low thresholds from the global image. Without considering the amplitude of the edge gradient of the image in different regions, the selection of the high and low thresholds is not easy to achieve, and the edge image is discontinuous or even lost [8]. In order to optimize the Canny algorithm, this paper proposes an improved image edge detection algorithm, from the local optimization of the selection of high and low threshold.

The rest of the paper is organized as follows. In Section 2 we present the traditional Canny algorithm. In Section 3 we present the improved Canny algorithm. In Section 4 we give the experimental results. Then, we draw conclusions in Section 5.

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TRADITIONAL CANNY EDGE DETECTION ALGORITHM

The basic idea of Canny edge detection algorithm is divided into four steps: first select Gaussian filter to smooth the image, and then calculate the magnitude and direction of the image gradient, use non-maximum suppression, finally set threshold and connect edge.

Gaussian Smoothing

In this step, using the Gaussian function is an important choice for classical Canny edge detection algorithm, which can smooth images for removing the noise before edge detection. Classical Canny algorithm generally use 1-D Gaussian function to smooth image and denoise. The function $f(x, y)$ is a grayscale image, The rows and columns of $f(x, y)$ are convoluted separately. Then we get the filtered image $I(x, y)$.

$$G(x) = \exp(-x^2 / 2\sigma^2) / 2\pi\sigma^2 \tag{1}$$

$$I(x, y) = [G(x)G(y)] * f(x, y) \tag{2}$$

Where σ stands for the standard deviation (size) of the Gaussian filter, it controls the smoothing degree, so σ plays a very important role in image edge detection.

Calculation of the Image Gradient

Because there are drastic changes in gray scale at the edge of the image, the traditional Canny edge detection algorithm usually selects a 2×2 neighboring area to get the magnitude and direction the gradient. The first order derivative on X and Y directions can be got from following formulas:

$$M(x, y) = \sqrt{K_x^2(x, y) + K_y^2(x, y)} \tag{3}$$

$$D(x, y) = \arctan[K_y(x, y) / K_x(x, y)] \tag{4}$$

$$K_x = (-S_1 + S_2 - S_3 + S_4) / 2 \tag{5}$$

$$K_y = (S_1 + S_2 - S_3 - S_4) / 2 \tag{6}$$

Where $M(x, y)$ stands for the image gradient magnitude, $D(x, y)$ stands for the image gradient direction, S_1, S_2, S_3, S_4 are the pixel value of the image $(x, y), (x, y+1), (x+1, y), (x+1, y+1)$, respectively.

Non-maxima Suppression of the Grad value

Non-maxima suppression can effectively locate the edge and suppress the occurrence of false edges. Canny method uses the 3×3 neighboring area to compare a pixel with its two adjacent pixels along the gradient direction. If its M(i, j) is bigger than the two adjacent have, the pixel will be marked as a candidate edge point, otherwise it is not an edge point.

Image Threshold Setting and Edge Connection

Thresholding is a widely used technology in image, Canny method uses high and low thresholds to segmentate image which have been non-maxima suppression of the gradient. If the gradient of the edge is bigger than the high threshold, the pixel will be marked as a candidate edge point, If the gradient of the edge is between the low and high threshold, we analysis whether there is a point greater than the high threshold around the pixel, and if it is present, it is the edge point, otherwise it is not the edge point. The edge points of the candidate edge that are attached to the edge will be marked as edge points. Now, the edge image is obtained. This step reduces the effects of noise on the edge of the edge image.

Defects in Traditional Canny Algorithm

The traditional Canny algorithm uses Gaussian filtering and first order difference equation to calculate the gradient amplitude, which leads to poor anti-noise ability, prone to pseudo-edge, What's more, the thresholds are man-made, It is not conducive to edge detection in complex situations.

IMPROVED CANNY DETECTION ALGORITHM

Image Preprocessing

Because the traditional Canny algorithm uses Gaussian filtering, which makes the edge detail seems blurry. To solve this problem, the median filter can be used to preserve the details of the image and remove the noise.

Euclidean distance [10] is widely used in the field of image processing, using the Euclidean distance squared filter to enhance the edge of the image. We make a filter based on Euclidean distance, The filter considers the influence of the horizontal and vertical axis direction and $45°, 135°$ the direction pixel value on the central pixel value, The closer to the center pixel, the greater the weight of the impact on the center pixel. The filter first determines the size of the filter template. And then according to the square distance of the European distance from the template from the center pixel farthest from small to large to fill in. We select a 3×3 template which is divided into horizontal and vertical axis direction and $45°, 135°$ direction. The filter is calculated as follows:

$$f(x,y) = \sqrt{f_{xy}^2(x,y) + f_{45°135°}^2(x,y)} \tag{7}$$

$$f_{xy} = \begin{bmatrix} 0 & 2 & 0 \\ 2 & -1 & 2 \\ 0 & 2 & 0 \end{bmatrix} \quad f_{45°135°} = \begin{bmatrix} 2 & 0 & 2 \\ 0 & 0 & 0 \\ 2 & 0 & 2 \end{bmatrix}$$

Where, filter can be divided into row and column filters as f_{xy}, it can be divided into $45°$ and $135°$ direction filters as $f_{45°135°}$.

In order to illustrate the feasibility of the above method image edge enhancement, verification analysis was performed using a vertical step edge linear model (shown in Figure 1 (a)) and a vertical bevel edge linear model (Figure 1 (b)). The results of filtering the two linear models by the Euclidean distance squared filter are shown in Fig. 1 (c) and (d), respectively. From the results analysis, we can see that the edge value of the filtered edge pixel is larger and the edge of the image is enhanced. Although the edge of the filtered edge is larger than the original edge, it is well processed when the final edge of the algorithm is refined, without affecting the accuracy of the edge detection.

2	2	2	1	1	1
2	2	2	1	1	1
2	2	2	1	1	1
2	2	2	1	1	1
2	2	2	1	1	1
2	2	2	1	1	1

(a)

3	3	3	2	1	1
3	3	3	2	1	1
3	3	3	2	1	1
3	3	3	2	1	1
3	3	3	2	1	1
3	3	3	2	1	1

(b)

21	21	17	15	11	11
21	21	17	15	11	11
21	21	17	15	11	11
21	21	17	15	11	11
21	21	17	15	11	11
21	21	17	15	11	11

(c)

32	32	28	21	15	11
32	32	28	21	15	11
32	32	28	21	15	11
32	32	28	21	15	11
32	32	28	21	15	11
32	32	28	21	15	11

(d)

FIGURE 1. Edge enhancement results

Improved Gradient Amplitude and Direction Calculation

In this paper, the Frei-Chen algorithm is used to calculate the gradient amplitude, which makes up the deficiency of the traditional gradient amplitude algorithm. The calculation method is shown in (8) - (12).

$$A_x = (S_1 + \sqrt{2} \times S_2 + S_3 - S_4 - \sqrt{2} \times S_8 - S_9) \div 2\sqrt{2} \tag{8}$$

$$A_y = (S_1 - S_3 + \sqrt{2} \times S_4 - \sqrt{2} \times S_6 + S_7 - S_9) \div 2\sqrt{2} \tag{9}$$

$$A_{45^\circ} = (\sqrt{2} \times S_1 - S_2 - S_4 + S_6 + S_8 - \sqrt{2} \times S_9) \div 2\sqrt{2} \tag{10}$$

$$A_{135^\circ} = (-S_2 + \sqrt{2} \times S_3 + S_4 - S_6 - \sqrt{2} \times S_7 + S_8) \div 2\sqrt{2} \tag{11}$$

$$A = \sqrt{A_x^2 + A_y^2 + A_{45^\circ}^2 + A_{135^\circ}^2} \tag{12}$$

Where S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8 are the pixel value of the image $(x-1, y-1)$, $(x-1, y)$, $(x-1, y+1)$, $(x, y-1)$, (x, y), $(x, y+1)$, $(x+1, y-1)$, $(x+1, y)$, $(x+1, y+1)$, respectively.

The improved gradient direction is calculated as follows:

$$D_A(x, y) = \arctan[A_y / A_y] \tag{13}$$

An Algorithm for Improving the Value of High and Low Thresholds

The high and low threshold value of traditional Canny algorithm is artificially set, which results in poor adaptability. It is necessary to use the Otsu algorithm to select the high and low threshold to improve the Canny algorithm's adaptive ability. At present, many scholars directly use Otsu algorithm to calculate the entire image gradient amplitude to get the best threshold as a high threshold T_h, set $T_l = T_h / 2$ as a low threshold. In the actual image, the image is affected by factors such as acquisition environment and hardware. The edge gradient intensity varies from region to region, In fact, the global Otsu algorithm is used to divide the gradient amplitude, and it is easy to ignore the local weak gradient amplitude, which produces a large deviation, resulting in poor edge image continuity, or even lost. n is the number of pieces of the image partition, t_i is the local optimal threshold for the corresponding segmented image. The formula is as follows:

$$T_h = \frac{1}{2 \times n} \sum_{i=1}^{n} t_i \tag{14}$$

In this section, we compare the performance of our proposed method with the method from references [8], take the Lena image of figure 2 as an example, the pixel size is 512×512, the image is divided into 200×200 pixels. If the partitioned area is not an integer, the fractional part is rounded. In the case of using the image preprocessing and gradient amplitude calculation method in this paper, by comparing this method with the references [8] to determine the threshold of the method, Lena image is divided into four local regions, Table 1 for the different areas of the map with Otsu algorithm to obtain the best threshold.

TABLE 1. The optimal threshold for different regions

area number	threshold
1	0.1569
2	0.1490
3	0.2000
4	0.2039

The high threshold value obtained by formula (8) is 0.0887, while the high threshold obtained by references [8] method is 0.1725. Lena image edge extraction, Lena obviously have broken the crown of lines, and the method to detect the image edge line is clear, has good continuity, the edge details are complete. According to the above analysis, this paper combines the idea of local Otsu algorithm to obtain the mean value, and the high threshold value obtained is more reasonable than the high threshold obtained by the method of references [8].

In summary, the algorithm flow chart is shown in Figure 2.

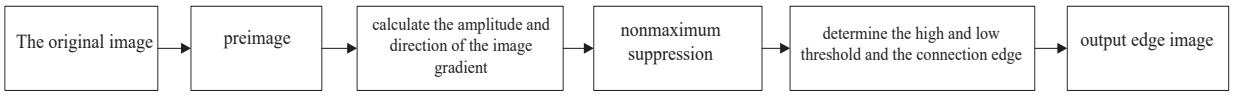


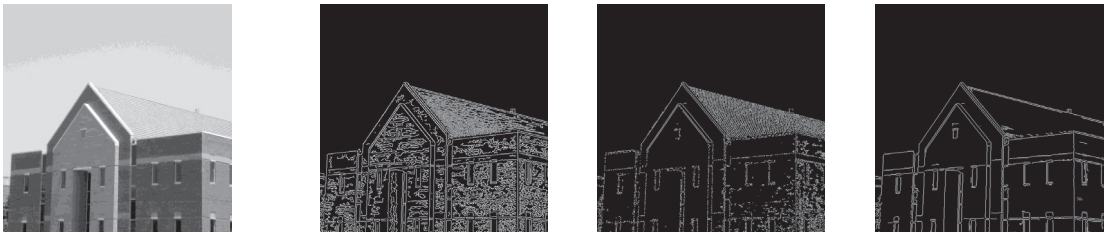
FIGURE 2. This paper algorithm flow chart

EXPERIMENTAL ANALYSIS

To test the performance of the algorithm, this paper choose the cameraman with size of the image, the size of architectural images and synthetic size of image as the test sample, with the traditional Canny algorithm, references [8] algorithm and this algorithm contrast experiment, analysis of the experimental results.

Subjective Evaluation

The results of the experiment are shown in figure 3, (b) are the results of image edge detection of traditional Canny algorithm, the edge image is more complete, but there are many false edges and noises, which can not satisfy the requirement of edge image accuracy. Figure (c) are the results of image edge detection of [8] algorithm. Its algorithm to pseudo-edge and suppression of noise is strong, but the detection of edge continuity is poor, and even local edge loss. the edges of the human part are discontinuous and missing, and some edges of the image of the right floor cannot be detected. In the image (c), the edge of the image is missing, and the edge image is far from the actual image. Therefore, the algorithm of this paper is able to detect the edge of the image with a relatively complete image edge, and the edge image has a strong continuity, the pseudo-edge and the noise are small. It is not difficult to illustrate that this algorithm is better than the previous two edge detection algorithms.



(a) The original image (b) Traditional Canny algorithm (c) Method in reference [8] (d) The Method of this paper

FIGURE 3. Effects of different edge detection algorithms

Objective Evaluation

Pratt proposes that the quality factor of edge detector can estimate the match between ideal edge and actual edge [13]. Quality factor is also an objective measure of edge detection effectiveness. Its quality factor calculation method is shown in formula (15).

$$R = \frac{1}{\max(I_A, I_I)} \sum_{i=1}^{I_A} \frac{1}{1 + ad^2} \tag{15}$$

In the formula, I_A represents the number of the actual edge points and I_I represents the number of ideal edge points. The proportionality constant is 0.1. d represents the vertical distance between the actual edge point and the ideal edge point. The values of the quality factor R are usually between 0 and 1, when the value is 1, the effect of edge detection is considered as the best situation.

The ideal edge of natural image is difficult to extract accurately, which is not good for evaluating edge detection method, In this paper, artificial synthetic images (shown in Figure 4), extract the ideal image edge for comparative analysis experiment. The synthetic image is tested in the original image, Gaussian noise and salt and pepper noise respectively, and the corresponding quality factor R value is obtained. The experimental results are shown in table 2.

TABLE 2. *R*-values of different algorithms for the artificial image with noise added

algorithm	The original image	Gaussian noise		Salt and pepper noise	
		0.01	0.05	0.01	0.05
traditional Canny	0.9549	0.1253	0.1215	0.3045	0.1719
Reference [8]	0.9124	0.6352	0.6735	0.4973	0.2289
improved algorithm	0.9382	0.9417	0.7254	0.9379	0.9392

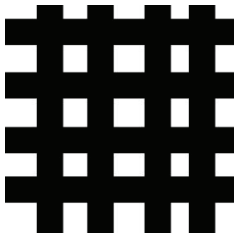


FIGURE 4. Testing image

In the absence of adding noise, the quality factor R of the three algorithms is high and close, indicating that the real edge detection accuracy is high. In the case of adding different Gaussian noise, the accuracy of the edge detection of the traditional Canny algorithm is drastically decreased. The accuracy of the edge detection accuracy of the algorithm from reference [8] is slightly smaller. The accuracy of the edge detection in this paper is only in the case of adding Gaussian noise, but it is higher than the traditional Canny algorithm and the reference [8] algorithm.

In the case of adding different salt and pepper noise, the accuracy of the edge detection of the traditional Canny algorithm is larger than that of the traditional Canny algorithm. The accuracy of the edge detection in the reference [8] is also greatly reduced. The accuracy of the edge detection in this paper is high, which indicates that the accuracy of edge detection is better than that of the above two algorithms.

From the above analysis it is not difficult to see this algorithm than the previous two algorithms have a better advantage.

CONCLUSION

An improved edge detection algorithm based on Canny algorithm is presented in this paper. Our method use the media filtering and filtering based on the method of Euclidean distance, which will replace the traditional Gaussian function for denoising. Then, we calculate the image gradient, non-maxima suppression, which based on Frei-chen. We improved the selection of high and low threshold values. Experiments show that this algorithm uses the optimal threshold of the region to replace the overall threshold for the idea of optimizing the threshold automatically set the algorithm, has a good anti-noise ability to improve the accuracy of edge detection.

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