The Canny Edge Detection and Its Improvement

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Abstract. To solve the problem of the traditional Canny edge detection operator has the weaknesses in excessive smoothing image and adaptability, and improved the parameter Sigma and the method to obtain high threshold. We did experiments with gray image of two cases with noise and without noise. The experimental results show that the improved Canny edge detection operators can balance eliminating noise from getting more edge information, which has the well continuity of the edge detection, and can detect the edge detail of the image. According to the image adaptive calculation, the improved algorithm has the advantage of low computational complexity, less calculation time.

Keywords: Canny edge detection, Edge gradient, Edge and texture.

1 Introduction

Edge information transfers the important information of the image, which is an important factor to affect the visual effect. Gray values adaptive to calculate low threshold edge detection. Edge detection is an important part of the image processing, by which we can acquire useful information of the target image and provide the basis for the target image processing. Therefore, the study of edge detection operators has always been very active, and also many practical edge detection methods [1] have been proposed.

Edge detection operators are mainly divided into the differential method, the optimal operator method, and the method based on mathematical morphology. First order differential method of Robert operator, Prewitt operator, Sobel operator, Kirsch operator, etc. Second order differential operator such as Laplace differential operator; the best operator method has the Laplacian of Gaussian, LoG and Canny operator.

The traditional Canny edge detection operator is still insufficient in excessive smoothing image and adaptability [2]. This paper consider and improve it from both local information and global information: (1) the original operator using a fixed parameter (standard deviation) of the Gauss filter, improved for Gaussian filter according to the local image variance and minimum variance adaptive parameter; (2) The edge detection which the original operator to set the gradient threshold, improved for the image based on the mean variance and average gray values adaptive to calculate low threshold edge detection.

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2 Traditional Canny Edge Detection Operator

The steps of the traditional Canny edge detection operator as follows:

Step 1: Using the Gauss function $G(x, y, \sigma)$ of smoothing filtering to the image f(x, y), Gauss function expression as formula (1):

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

In practical application often use $\sigma = 1.4$ as Gauss template.

$$\frac{1}{115}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix}$$

To compute the gradient of the point (x, y) by formula (2) and (3):

$$\nabla g(x, y) = \nabla(G(x, y, \sigma) * f(x, y)) = \nabla(G(x, y, \sigma) * f(x, y) \tag{2}$$

$$E_x = \frac{\partial G(x, y, \sigma)}{\partial x} * f(x, y) \qquad E_y = \frac{\partial G(x, y, \sigma)}{\partial y} * f(x, y) \tag{3}$$

Calculate the gradient amplitude $|\nabla g(x, y)|$ which reflects the size of the edge intensity .The calculation method of $|\nabla g(x, y)|$ which refers to gradient amplitude of Pixel (x, y) are as formula (4) shown, the direction of the gradient is perpendicular to the edge direction.

$$|\nabla g(x, y)| = \sqrt{E_x^{\ 2} + E_y^{\ 2}} \tag{4}$$

$$\theta(x, y) = \arctan(\frac{E_y}{E_x}) \tag{5}$$

Step 2: Doing gradient with "non-maxima suppression". In order to refine and enhance the gradient amplitude of roof, to all pixels, we reduce all that isn't the roof type of peak gradient amplitude in the gradient direction.

Gradient direction angle calculated from (5) show that each pixel of the image has four possible directions when connected with the adjacent vertex: 0 degrees (horizontal direction), 45 degrees (diagonal), 90 degrees (vertical direction), 135 degrees (negative diagonal). The edge direction must be the closest one in four kinds. Direction angle is classified to the four angles:

0° : 0°~22.5°, 157.5°~180° ; 45° : 22.5°~67.5° ;
90° : 67.5°~112.5° ; 135° : 112.5°~157.5°

For all the edge points in the image, if the gradient magnitude in the above direction angle direction is less than or equal to the amplitude between the two adjacent points along the line gradient, the value of $|\nabla g(x,y)|$ is assigned zero; If not, the value of $|\nabla g(x,y)|$ is not changed. After the non-maxima suppression, refined the previous wide ridge region, and made it become only one pixel wide. In the process of non-maxima suppression, did not change the roof height.

Step 3: Dual-threshold segmentation and edge stitching. Even though with non-maxima suppression, pseudo edge still exists. Namely, using a single threshold processing, it is difficult to choose the appropriate threshold. The solution is using dual-threshold, which combined the high threshold T_h with the low threshold T_l , usually the $T_l : T_h$ ratio is $2:3$.

3 The Improvement of Traditional Canny Edge Detection Operator

Traditional Canny edge detection operator has two shortcomings of over-smooth images and easy loss of edge details [9]. In recent years, three kinds of adaptive improvement method have been appeared to improve the insufficiency of the traditional Canny edge detection operator. The first one is making improvement for excessive smooth caused by single Gauss filter parameters; the second is making improvement for false edges or loss local edge caused by man-made setting level threshold; the third improvement is to integrate the first with the second.

This paper is based on the complexity and time consideration, on the basis of literature [1] and [2], is the third category to improve the traditional Canny edge detection operator. Specific improvements are: (1) on the basis of the iterative method to obtain parameter Sigma in literature [2], in order to achieve easy, we computed the value of Sigma utilizing the image of the local characteristics and global characteristic adaptive. (2) According to the image of the overall feature to set high and low threshold, in no need of extra hardware equipment than in the case of literature [1] of the lower computational complexity. The detailed description of these two aspects as follows.

(1)The Improved Access Method about the Parameter Sigma of Gauss Filter

When the Gauss filter start to smooth filter, the bigger the parameter of Sigma (standard deviation) is , the higher frequency signal suppression effect, when avoid the false edge, this operator can make the edge blurred [3];The Sigma smaller, kept the edge detail information, but it will be diminished the ability of noise. The traditional Canny edge detection operator, selects the parameter Sigma man-made to the edge of the image region which does not have a consistent to fit, that may bring Gauss filter excessive image smoothing. Then, according to the local characteristics of image edge and the global image characteristic how to compute the value of Sigma, the method which the present paper will discuss the improvement of the adaptive selection of the parameter Sigma.

Firstly, we discuss the impact of different image region on the value of Sigma. Assuming that the original image is $I(x, y)$, the edge region is $I_e(x, y)$, the flat region is $I_s(x, y)$, we discuss this both two cases of noise-free and noisy.

①In no noise conditions. If the flat region $I_s(x, y)$ of a $N \times N$ window, every pixel gray approximately equal, variance is approximately zero, then do not need a large degree of smoothing, so we only need to take a very small value to the Gauss filter can be used; if the edge region $I_s(x, y)$ of a $N \times N$ window with the edge points, then the pixels within the window with the edge pixels mean the value of points will have bigger difference, variance will be larger, then the Sigma value only slightly larger than the flat region value.

②In noisy conditions. In flat and the edge of the region, the value of the pixels in the $N \times N$ window of pixels within the window mean spreads are larger, is also a great variance, so it is necessary to take a large value of Sigma.

From the above analysis, the value of Sigma is proportional to the window of the variance. According to the actual situation, not only to obtain the corresponding .The value of Sigma will be smoothed image but also preserve the image edge. Considering the minimum variance reflects the image of the overall characteristic, the $N \times N$ window variance reflects local characteristics, so the minimum variance and local variance as the parameter Sigma measurement standard. It can give attention to both the window within the local information and global information. In conclusion, the parameter of Sigma acquiring method as showed in formula (6):

$$\sigma = V / V_{\min} \tag{6}$$

The variance is

$$V = \sum_{n=1}^{N \times N} (I(x, y) - M)^2$$

The average gray value is

$$M = \frac{1}{N \times N} \sum_{n=1}^{N} I(x, y)$$

The minimum variance is $V_{\min} = \min(V)$ .There are two special cases to consider: one is a pixel value that equals to the minimum variance, namely $\sigma = 1$, but this value for slow changing edge is too big, and removed the noise and a lot of slow changing edge blurred out; another kind of circumstance is when the pixel variance is large, the Sigma is great, a lot of clear edges will be filtered out.

In order to solve the above problems, combined with the adaptive thought, add a weight to the parameter of Sigma ,the formula (1) revised as: $\sigma = kV / V_{\min}$,the value of k is $1/M$ (M in 0~ 1.). Then V is small, the value of Sigma should be smaller than by formula (6) the calculated value, it can prevent the slow changing edge blurring; when V is large, the value of Sigma is also smaller than by formula

(6) the calculated value, so it does not overly smoothed image. Therefore, use $\sigma = kV/V_{\min}$ substitution of Gauss function type (6) is

$$G(x,y) = \frac{1}{2\pi(\frac{V}{M \times V_{\min}})^2} \exp(-\frac{x^2+y^2}{2(\frac{V}{M \times V_{\min}})^2}) \tag{7}$$

The value of Sigma is fully references each window gray information, the whole image of gray information, so that is conducive to effective at removing noise and retain more edge information.

(2) The improvement of obtaining the high threshold

In the Canny edge detection operator, the high and low threshold selection determines the detected edge information and its continuity. Edge detection threshold is higher starting point, the smaller high threshold is, the more retaining edge information, but it can also cause more false edges; the high threshold, reduced the false edges, but also ignored some edge information, causing edge discontinuities.

In order to detect all the details of the whole image edge, consider the overall image characteristics when choose the high threshold. Image mean variance and average gray value are reflected in its entirety parameter, so they can be used as high threshold selection standard. Above all, the value of T_h can be

$$T_h = V_{ave}/M_{ave} \tag{8}$$

Among them, the image variance is

$$V_{ave} = \frac{1}{W \times H} \sum_{i=1}^{W \times H} V_i ,$$

The average gray is

$$M_{ave} = \frac{1}{W \times H} \sum_{i=1}^{W \times H} I_i(x,y) .$$

H and W are the height and width of the image. But this calculated high threshold will result in too many false edge , also join a weighting parameter k , namely $T_h = kV_{ave}/M_{ave}$, and through the experiment, the best value of k between 0.2 and 0.5. In order to reduce the amount of computation, low threshold still using high and low threshold ratio is $2:3$ to calculate, namely the low threshold is $T_l = 2T_h/3$.

4 The Description and Realization of the Three Improved Canny Edge Detection Operator

Above all, the operator calculates the value of Sigma automatically by the Gaussian function, using Sigma of the adaptive filter in this paper. When use adaptive filter to calculate the high and low threshold according to the gray level information of the image itself, to detect more edge information. The realization needs six steps as follows:

Step 1: According to the image I , in accordance with the parameter of Sigma the calculation method to calculate the value of Sigma.

Step 2: Operator obtained after the smoothness of the image I filtered image I' .Image I' get by convolution of image I and the adaptive filter G .

Step 3: Calculate the image gradient magnitude and direction.

Step 4: Return to step 3 in gradient non maxima suppression.

Step 5: According to the image I' .In accordance with the high threshold value method to obtain a high threshold, and calculated the corresponding low threshold.

Step 6: Edge detection and connection. The process of realization as showed in figure 1.

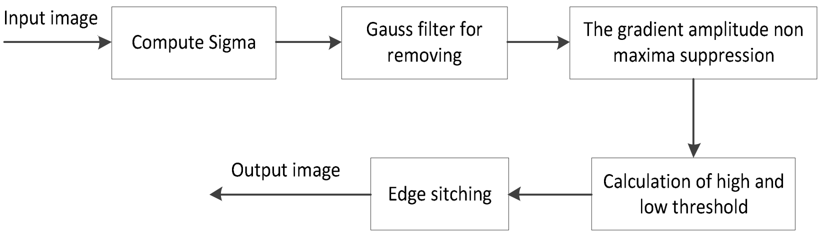


Fig. 1. The Flow Chart of the Improved Canny Edge Detection Operator

The core parts of the realization of ideas are as follows (MATLAB program fragments):

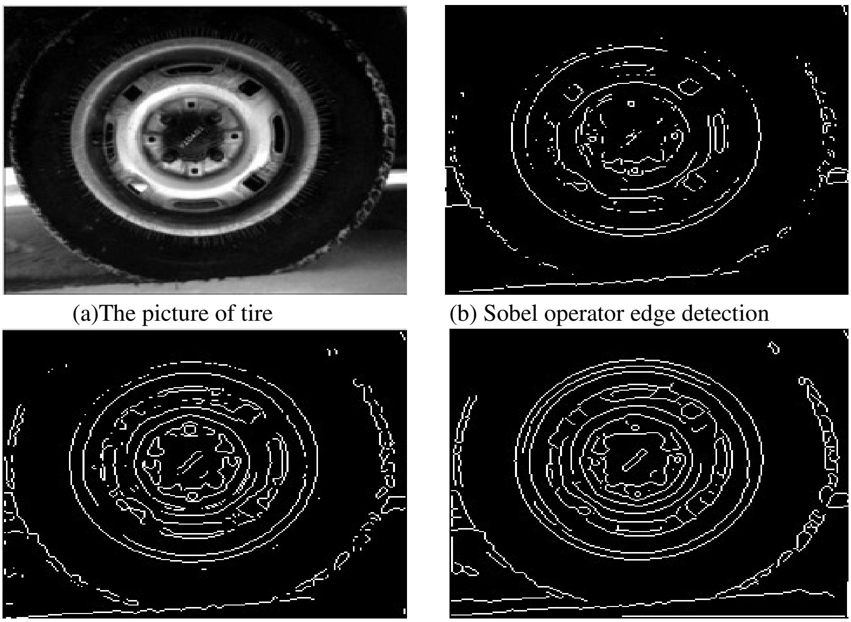
```
Input an image I
Find the size of I
%Gauss filter parameter Sigma automatic acquisition
For x=1 to width do
   For y=1 to Height do
        Calculate local variance.
Find the minimum variance.
        Calculate local mean.
        Calculate Sigma.
        Smooth I by Gaussian filter with Sigma.
    End for
End for
%High threshold improvement method for obtaining
For x=1 to width do
  For y=1 to Height do
Calculate the mean of the whole matrix' gray value.
        Calculate Mean variance.
        Calculate the high threshold.
    End for
End for
```

5 Experimental Results and Analysis

Select RGB color pictures of the car of tire as the experimental object, first carries on the color fusion, using the improved operator, Sobel operator and the traditional operator for experiments respectively, and finally compared the experimental results. We are first under noise-free conditions for image edge detection.

Experiment (1): At the case of no noise performance comparison of edge detection operator

The experimental results show in figure 2. As we can see from Figure 2, the Sobel operator can detect the horizontal direction and the vertical direction of the edge, the traditional Canny operator detects edge information is less, In this paper, our method have closed edge; the operator detects more edge information, and can detect the closed ring edge in the tire, the most important is detecting gray time-varying image edge efficiently.



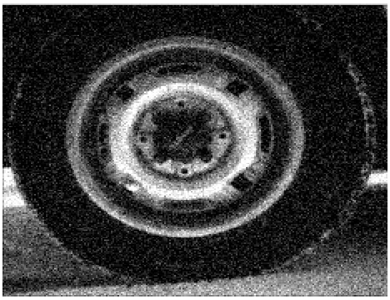
(a)The picture of tire (b) Sobel operator edge detection

(c) The traditional Canny operator edge detection (d) Improved Canny edge detection

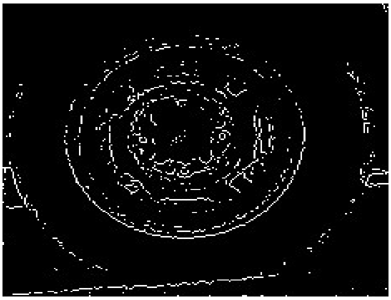
Fig. 2. The Chart is without Noise Free Edge Detection Effect

Experiment (2): Adding noise under the edge detection operator performance comparison

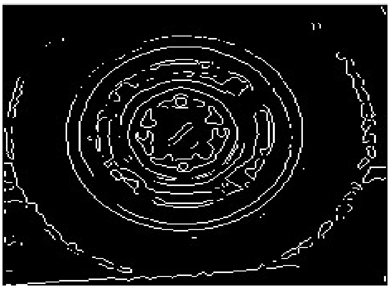
Do experiments on the addition of noise in the image of tire .The experimental results show in Figure 3, the Sobel operator is very sensitive to noise, applied to image noise can seriously affect the quality of the traditional edge detection; Canny operators have the noise removal ability, but on the gray slow changing edge detects edge information is less, while the detected edge continuous closed is poor; and the operator can remove noise, gray slow changing edge detection to more edge information, the detected edge continuous closed property is better, and can detect the edge details.



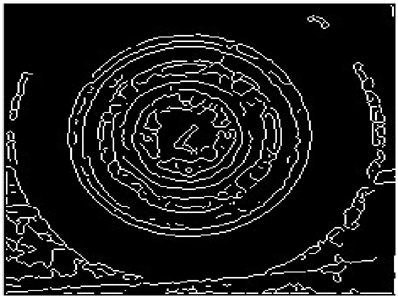
(a)The addition of noise of the tire image



(b) Sobel operator edge detection



(c) The traditional Canny operator edge detection



(d) Improved Canny edge detection

Fig. 3. The Chart is without Noise Free Edge Detection Effect

6 Conclusion

In this paper, according to the weaknesses of easy to lose the edge details with the traditional Canny edge detection operator ,we improved method to get the parameters and the high threshold, with noise and without noise , for tires of the car ,utilize Sobel operator, traditional Canny operator and improved Canny operator for edge detection, respectively.

Experimental results show that the improved Canny operator can eliminate noise and get more edge information. Detected edge continuity is better, and can detect the edge details of the whole image. According to the image adaptive calculation, the improved algorithm has the advantage of low computational complexity, less calculation time, etc.

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