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Enhanced Boundary Detection Method Based on Canny Theory

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Abstract: With the quick development of computer image detection technique, image boundary inspect method has become the field of image processing and computer vision research focus, digital image boundary inspection is image segmentation, image recognition, image analysis for instance area shape extracting the important foundation. Based on Canny operator manually select the threshold improperly, which result in edge detection has some ineffective shortcomings. In this study, the method is presented an reinforced Canny boundary inspection to automatically produc an adaptive threshold for Canny edge detection operator. In the algorithm, it can create the threshold parameter automatically, by the mean square error and average gray of the image. Therefore this method can avoid errors caused by manual input and obtain a desired edge effect.

Key words: Edge detection, canny operator, adaptive threshold

INTRODUCTION

As a low-level visual processing, edge detection technology is an old and young subject. Date back to 1959, the literature (Han and Lin, 1997) mentioned the edge detection. L.G Roberts earliest researched edge detection systematically in 1965 (Nallaperumal *et al*., 2007). Since then, the new theories and methods on the edge detection aspects have being emerged. On the one hand the reason might be the importance of the subject, on the other hand reflects the depth and difficulty of the issue. Edge detection theory and methods have yet to be improved further.

With the deepening of the research, people gradually realize that the visual procedure is a multi-resolution information processing. In different resolutions, the extracted information is different and the edges of the images are also with multi-resolution. Resolutions are filter scales in the filtering,the difference of edges exists in different scales using different scales edge detection to operate the image, we can get an image in different resolutions on the description.Usually small-scale detection operator can get more image detail,but more sensitive to noise,while the large-scale operators not so sensitive to noise but will ignore the image details.Witkin (Ng and Ma, 2006; Wang *et al*., 2006) proposed the idea of scale space for multi-scale edge detection firstly which research deeply in terms of multi-resolution. He thought that the signal and the extreme points of the first derivative can usually reflect the basic skeleton and are the desciptors of the different types of the signal. Continuously changing spatial scale, implement the image convolution and track its extreme points and identify the singularity of the new extreme point. The idea of multi-scale opened the space of the edge detection and multi-scale edge detection method is also very active, there have been many research results (Wang *et al*., 2006; Hanmandlu *et al*., 2006; Li and Zhang, 2003). As a powerful tool for processing the singularity signal, the wavelet edge detection researches and applications also achieved important results, have been fully utilized. Mallat (Demigny and Kamle, 1997) effectively applied the multiscale analysis in the field of computer vision to the decomposition and reconstruction of wavelet transformation and the algorithm was also applied to the decomposition and reconstruction of the image. In addition, he also unify the wavelet edge detection, LoG operator and the optimal Canny detection operator in the wavelet and express the importance of the idea of multi-scale edge detection clearly. Accordingly the multiscale wavelet edge detection method has also achieved many results (Li and Zhang, 2003; Demigny and Kamle, 1997; Masoud and Bayoumi, 1995; Liqin *et al*., 1994).

Recently, the image detection method using using a variety of new theoretical tools has been used widely (Pal and King, 1983). For example, the edge detection operator based on morphological, the statistical methods for detection techniques (Demigny and Kamle, 1997), the neural network detection, the fuzzy theory

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detection techniques, the use of detection techniques (Prewitt, 1970), edge detection technique based on the fractal characteristics and other studies have also appeared, showing very active.

THE TRADITIONAL CANNY EDGE DETECTION OPERATOR

Traditional canny edge detection operator: The basic idea of traditional canny edge detection operator is as folloes. First, for the processing image selects certain gaussion filter to smooth filtering and calculats gradient magnitude and direction of each pixel; Then, using a technology called Non Maxima Suppression to process the smooth image; Finally using double threshold method to detect and connect image and obtain the edge image.

The specific algorithm of Canny Operator is introducted as follows (Canny, 1986):

Smooth the image: Canny linear operator is a derivative of gaussian function, Corresponding to the image using the gaussian function to smooth and gradient to calculate. The operator is particularly sensitive to the edge for the most direction dramatically changed but along the edge direction is not sensitive. Its role is a smooth operator.

Canny operator is the optimal approximation operator for the product of the signal-to-noise ratio and location. First, Canny algorithm uses an one ordered derivative of a two-dimensional gaussian function to smooth the image, A two-dimensional gaussian function as:

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

The gradient vector is:

$$\nabla G=\begin{bmatrix}\partial G/\partial x\\ \partial G/\partial y\end{bmatrix} \tag{2}$$

Using decomposition methods to improve the speed, the two filter convolution model of ∇G is decomposed into two one dimension filtering:

$$\frac{\partial G(x,y,\sigma)}{\partial x}=kxe^{\frac{x^2}{2\delta^2}}e^{-\frac{y^2}{2\delta^2}}=h_1(x)h_2(y) \tag{3}$$

where k is constant, σ is the parameters of gaussian filter, it controls the smoothness.

For small filter, although the position precision is high, signal-to-noise ratio is low; so the selection of appropriate gaussian filter parameters σ is very important.

4	3	2
1	x	1
2	3	4

Fig. 1: Relationship between neighboring pixels

Computing the gradient amplitude and direction: The traditional Canny algorithm uses a finite difference of 2×2 neighbourhood of first order partial derivatives to calculate the gradient amplitude and gradient direction of the data array g (x,y) having been smoothed. The x direction and y direction partial derivatives of the two arrays are:

$$E_x=\frac{\partial G(x,y,\sigma)}{\partial x}\times f(x,y) \tag{4}$$

$$E_y=\frac{\partial G(x,y,\sigma)}{\partial y}\times f(x,y) \tag{5}$$

The gradient amplitude |∇g (x, y)| and gradient direction θ (x,y) of each pixel (x,y) in the image f (x,y) are:

$$|\nabla g(x,y)|=\sqrt{E_x^{\ 2}+E_y^{\ 2}} \tag{6}$$

$$\theta(x,y)=\arctan\left(\frac{E_x}{E_y}\right) \tag{7}$$

|∇g (x, y)| reflects the strength of the edge, θ(x, y) perpendiculars to the direction of the edge.

Gradient magnitude for non maxima suppression: The direction of the gradient can be defined as shown in Fig. 1, that are identified as one of the four areas 1, 2, 3, 4. Then comparing different districts with different neighboring pixels to determine the local maximum. For example, If the gradient direction of the center pixel x belongs to 4 area, compare the gradient value of x to the gradient value of left, right, up and down adjacent pixel. Then look at gradient values of x whether or not are local maximum. If not, set the gray scale of pixels x to 0. This process is known as the Non maxima Suppression.

With double threshold to detect and connect the edge: Thresholding the gradient value for the Non maxima Suppression processed array, Get the edge array of the image.The edge array still exist false edge. The reason is the threshold τ is too low (false right) or the presence of shadows which can result in edges comparison weakened, or the threshold τ is too high which can result in some loss of contour (false error). So if using a single threshold to process, select the appropriate threshold is difficult. Generally we need to repeated experiments. Therefore the effective way is to choose two thresholds. Assuming the image of Non maxima Suppression processed is N [i, j]. It has two thresholds: high threshold T_1 and low threshold T_2 and $T_2 = \alpha \times T_1$ where α is scaling factor. With the double thresholda T_1 and T_2 act on image N [i, j] to get the edge array of two thresholds Q_1 and Q_2.

- Scan edge array Q_1, when scanning a non-zero value of the gradation pixel P, tracking the contour line of the starting point P until the end of the line Q
- In the edge array Q_2 finds Q' point which corresponds to Q in Q_1, search nonzero pixel gray value R in 8 neighbourhood or 4 neighbourhood of Q'. Then the R' in the corresponding point R of Q_1 includes to the edge array Q_1

Similarly, tracking array Q_1 to continue to search for the start point of the point R contours. Repeating the process loop, until the edge of the array Q_1 and Q_2 can not be proceeded.

Thus, the contour which is including the connection point P is completed, the point P is marked as visited. Repeat to find each contour in the edge the array Q_1, until circles could not find a new contour.

So far, canny operator edge detection is completed.

Deficiencies of the traditional canny algorithm: The traditional Canny edge detection operator exists several deficiencies:

Gaussian filter function of canny algorithm: In the practical application, the traditional Gaussian filter for the underlying process finds the following problems.

As the traditional Gaussian filter is isotropic and the edges of the image are high frequency signals and noise. using the traditional Gaussian filtering function, although it is beneficial to smooth the noise, it will cause a decline in the positioning accuracy and the features of smooth processed are difficult to be protected. So the edge fuzzification of the image is increased.

In addition, in the calculating, the value σ is fixed, so there have been some problems in the same degree of smoothing every direction, noise smoothing ability and positioning capability is contradictory.

When the value of the Gaussian filter σ is small, it has a high edge location accuracy but the image smoothing effect is weak and noise rejection is poor. So in the presence of noise it is unstable. To obtain a good noise suppressing effect, the value must be increased but it results in the template is increasing, the position of the edge shifts seriously and the calculation is increasing. Therefore, it detects the false edge and missing true edge of some of the details easily, it does not have adaptability, experimental results are not good.

Double threshold method in canny algorithm: The traditional Canny algorithm for high, low threshold repair discontinuous contour thought, it is segmentation the whole image by high and low threshold, there will be loss of edge information since the threshold set too high; So it can not take into account the local feature information of image. On the one hand local noise interference can not be eliminated, the other gray values will be lost slowly varying local edge, Leading the edge of object contour is not continuous, so that the detection effect is affected by. In addition, because the traditional Canny operator high and low threshold parameter is not characteristic of the image edge information to decide and different thresholds has great influence on the results for edge detection. In fact, the best effect of different image edge detection has different threshold. If simply using conventional Canny Algorithm does not have the adaptive capacity, low degree of automation but also detect false edges or missing local edge. Meanwhile, some important edge details may be due to interference or low contrast become blurred, weak. In the actual image Part of the edge details and noise may be similar and even has lower gradient magnitude. At this point, the traditional Canny algorithm using dual threshold method is difficult to suppress noise while preserving low intensity of edge, which influences the effect of edge detection in a certain extent. Therefore it is necessary to improve the traditional Canny algorithm, to obtain better image edge examination effect.

Because of the existence of these problems affected the practical application effect of Canny algorithm in this section, In this section, in order to solve the above problems (2) that the lack of double thresholds method, proposed a adaptive canny edge detection method, Through experiment, it achieves good effect in edge detection.

Algorithm realization of adaptive canny edge detection: When using the Canny operator to detect edges, the selection for high and low threshold is very important. the high threshold control starting point of the edge detection, the smaller the high threshold, the more you keep edge information but the false edge will also increase. On the contrary, although the higher threshold is, the greater it can effectively restrain for edge but also it will lose some edge information. So the high threshold should be determined based on the whole information of image and to get a good result for edge detection.

Difference between average grey value of image can make the Canny operator high threshold is not the same and even in the same average of the image, each pixel of the image may be different, or each pixel gray value is very average. So the image threshold value should also be different, that is mean square deviation of the image is also an important parameter to determine the high threshold. From what has been discussed above, we can see that to determine the threshold value of image, we use the two parameters: average grey value and mean variance of the image.

Based on this, this study proposes an improved Canny edge detection to generate threshold algorithm automatically:

The calculation method of average grey value F, the average variance E of the image is shown in the following formula:

$$F=\sum_{m=1}^{L_w \times L_h} E_m/(L_w \times L_h) \tag{8}$$

$$E=\sum_{m=1}^{L_w \times L_h} |E_m - F|/(L_w \times L_h) \tag{9}$$

where F, E, L_w, L_h, E_m stands for the average grey value, the average variance of image, image width, image height and the grey value of image each pixel. Algorithm can be described as follows:

```
int gray = 0, f = 0,e = 0, sqr = 0;
for ( every pixel)
{
gray = gray + pixel;
}
f = gray / ( HEIGE* WIDTH) ;% (The average gray value)
for ( every pixel)
{
sqr = sqr + abs( pixel - f) ;
}
e = sqr /( HEIGE* WIDTH) ;% (The average variance)
```

after the two important parameters (E and F) obtained, in order to calculate a better threshold according to the pictures of the two basic information automatically. we will be analyze the average grey value of image, the average variance. Through hundreds of different images in gray level, gray changing analyzed, we get the three important conclusions:

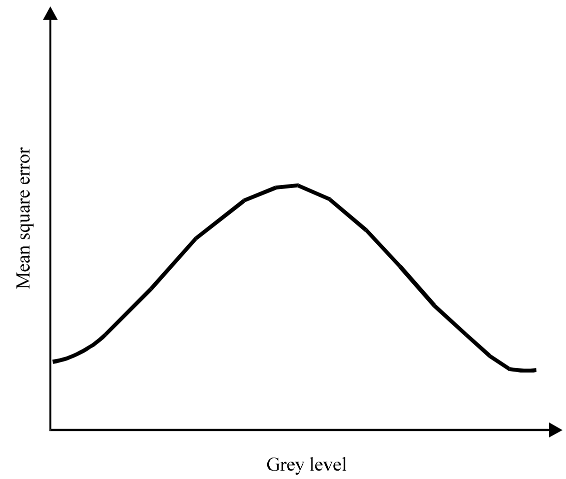

Fig. 2: Relationship between the mean square error and average gray level values

- The mean square error of the image with the average grey value (gray scale value between 0 and 255) increases, when it increases a certain extent, it will be reduced with the increasing of the gray value. It presents a "convex" shape (Fig. 2)
- The best threshold value of the image decreases with the average grey value increasing of the image
- The best threshold value of the image increases with the mean square error increasing of the image

Conclusion 1: Because when the gradation value is theoretically large or small, the image is the whole black or white color, so it has little difference between each pixel, which resulting in gray value variance is always smaller than the average of the image.

Conclusion 2: Because when the average gray of the image is small (ie darker image), if the threshold is small, we would get a lot of pseudo-edge, which is not conducive to get a good edge. With the increase of the average gray of image, threshold should be reduced so that the real edge can be detected.

Conclusion 3: Since the larger mean square error is, the larger gray value of each pixel of the image is. So it should take a relatively large threshold value, which can leave the filter to more edge information and obtain a processing result.

Based on these conclusions, Taking into account of the gray-scale of image is between 0 and 255 and with the increasing of average gray, threshold should be smaller.

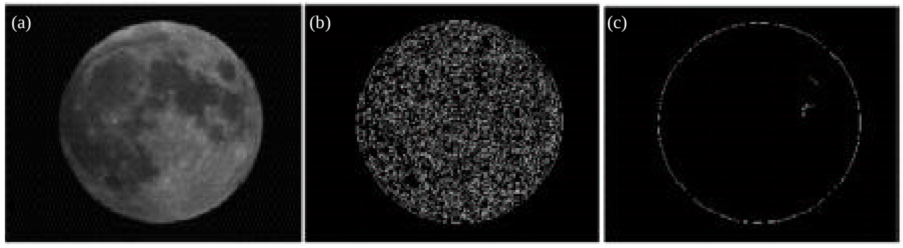

Fig. 3(a-c): Moon image and the test result, (a) Original image, (b) Traditional canny operator and (c) Improved canny operator

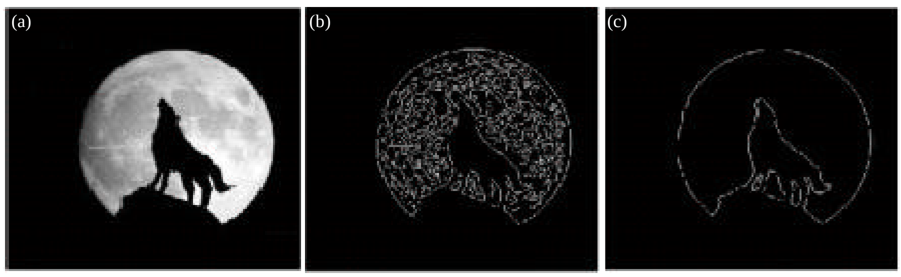

Fig. 4(a-c): Moon_wolf Image and the test results, (a) Original image, (b) Traditional canny operator and (c) Improved canny operator

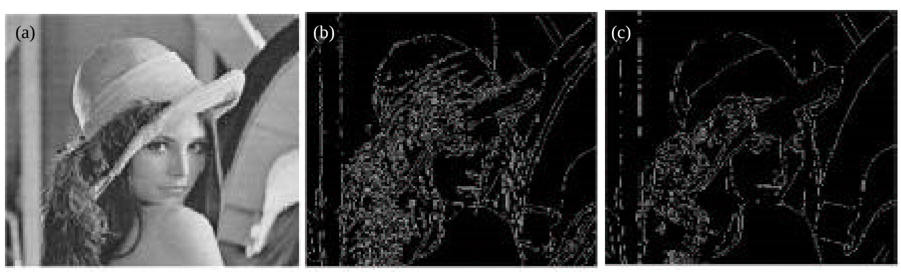

Fig. 5(a-c): Lena image and the test results, (a) Original image, (b) Traditional canny operator and (c) Improved canny operator

So in this study, using 255-F as a parameter of the improved algorithm. Meanwhile, the larger variance is, the larger threshold is, so in this study, using mean square error E as a parameter of the improved algorithm. Through a large number of image data experiments and statistical analysis, On the basis of the high threshold originally proposed in study (T_h = (255-F)/3+E), we come to a better detection algorithm that can be calculated automatically Canny edge detection algorithm for high threshold:

$$T_h = (255-F)/3+\sqrt{E} \tag{10}$$

where, T_h is the high threshold, In general, a high threshold of Canny operator 2-3 times of the low threshold. in order to reduce the amount of computation, the low threshold still use the traditional method of calculation. Assume the low threshold T_l:

$$T_l = T_h \times 0.5 \tag{11}$$

According to the experiment, the selection of low threshold gets the ideal result.

EXPERIMENT RESULTS AND COMPARISIONS

We sleect the Moon image, Moon_wolf image and Lena image as the images to be detected and compared with the traditional Canny operator in threshold detection effect, some experimental results as shown in Fig. 3-5.

Through the above simulation results, we choose some representative images for Fig. 3, 4 and 5 to compare. Their image average gray value differ sharply, the overall colors are gray and black. we can easily seen from the comparision of the effect of our algorithm as shown in Fig. 3 and 4. The traditional Canny operator obtains a smaller threshold, which leads to excessive edge information obtained. When using our algorithm in this study, because image gray smaller, so we get a larger threshold to obtain a desired.

CONCLUSION

In this study, under the framework of image engineering, we analyze the importance of edge detection, through read the knowledge of the literature on edge detection, we have a more comprehensive understanding of the status quo in the case of domestic and international research and in-depth study of the edge of the now mainstream detection Canny operator.

Based on Canny operator manually select the threshold improperly, which result in edge detection has some ineffective shortcomings. In this study, we proposed an improved Canny edge detection to automatically generate an adaptive threshold for Canny edge detection operator. In the algorithm, we can generate the threshold parameter automatically, through mean square error and average gray of the image. So we avoid errors caused by manual input and obtain a desired edge effect.

Experimental results show that in terms of the detection effect the edge detection algorithm has significantly improved. especially on the edge of the high value or low grayscale image acquisition, which is particularly evident and it has good continuity, strong adaptability and robustness.

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