Remote Sensing Image Edge-Detection Based on Improved Canny Operator

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***Abstract*—The edge details of the remote sensing image is key for the target detection with complex background. Traditional Canny detection operator requires human intervention, does not have the adaptive ability in the variance of Gaussian filtering and the threshold. Compound morphological smoothing replaces Gaussian filtering, can not only maintain the edge information, but also reduce noise impact. Then Otsu method can specify the threshold adaptively, the edge detected is more continuous, and can decrease the false edges. In order to extract the edges of the remote sensing image proposed an approach based on Canny edge detection operator. Finally, we refine the edge by using morphological structure element. The experimental results show that the improved Canny algorithm has a good anti-noise function and precision on image processing of remote sensing.**

Keywords-remote sensing image; edge-detection; Canny operator; compound morphological smoothing; Otsu method

I. INTRODUCTION

In the field of computer vision, edge is an important feature. People have done a lot of research of edge detection, and made a series of achievements. Typical first-order differential operators are Roberts, Prewitt, Sobel, and second differential operators are Laplace, LOG etc. These operators is simple in principle, easy to realized, and good real-time property. But they have poor anti-jamming performance and a little edge detail. The traditional method of edge detection based on emerged a new class of algorithms recent years, such as sphere fitting, adaptive smooth filter, morphology [1], wavelet transformation, data fusion, particle swarm optimization etc. Nevertheless, the Canny operator [2] by virtue of its better SNR and detection precision, is still widely used in image processing field.

1986 Canny proposed edge detection operator based on optimization algorithm, has a good SNR and precision, it is widely used in image processing, and some significant results have been achieved [3]-[9]. However traditional Canny operator has large amount of calculation, poor real-time, need to manually set a threshold, and detect edges have not met a single pixel. In real application, it is easy influenced by sorts of factors, and remain part of the false edge. So the application still has some limitations, In response to these problems based on the study of the improved Canny operator. Introducing composite morphological filtering, Otsu method[3]to detect image edge. And achieve a single pixel-precision edge extraction by morphological thinning operators, improve the precision and accuracy of edge detection.

II. TRADITIONAL CANNY EDGE DETECTION ALGORITHM

Wherever Times is specified, Times Roman or Times New Roman may be used. If neither is available on your word processor, please use the font closest in appearance to Times. Avoid using bit-mapped fonts if possible. True-Type 1 or Open Type fonts are preferred. Please embed symbol fonts, as well, for math, etc.

Canny proposed three standards of the edge detection algorithm:

(1) Good detection performance: neither miss the true edge points, nor get false edge points.

(2) Good location properties: detect edge points as near as possible to practical points.

(3) The only response: individual point has only one response, and inhibit false edge responses.

The basic principle of Canny operator is: use the arbitrary first-order directional derivative of two-dimensional Gaussian function to design noise filter, then search for local gradient maximum value from the filtered image, and to determine the edges of the image [10]. Algorithm specific steps are as shown in Fig. 1.

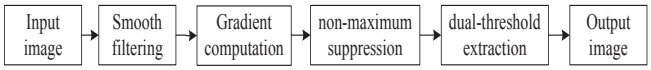

Figure 1. Canny edge detection process

A. Smooth Filter

Canny operator's noise filter adopt first-derivative of two-dimensional Gaussian function. Filtrate noise in image by convoluting with the image, and achieve the effect of smoothing the image[11]. Two-dimensional Gaussian function is:

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

Wherein (1) σ is the manually reset variance of the Gaussian filter function for controlling image smoothness. When σ is small, positioning accuracy is high and SNR is low. When σ is big, positioning accuracy is low and SNR is high. Should to make the appropriate choice, and general range is 1.0--2.0.

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Image after smoothing is: $g(x,y)=G(x,y)*f(x,y)$, $f(x,y)$ is the original image functions, * means convolution.

B. Gradient Computation

Traditional Canny operator uses 2×2 neighborhood first-difference to calculate gradient magnitude and gradient direction of $g(x,y)$. $G_x[x,y]$ and $G_y[x,y]$ are the x and y direction partial derivatives of point (x,y). Adopt first-difference approximate expression to calculate gradient magnitude and gradient direction, that is:

$$G_x[x,y]=[g(x+1,y)-g(x,y)+g(x+1,y+1)-g(x,y+1)]/2 \quad (2)$$

$$G_y[x,y]=[g(x,y+1)-g(x,y)+g(x+1,y+1)-g(x+1,y)]/2 \quad (3)$$

Gradient magnitude: $$M[x,y]=\sqrt{G_x[x,y]^2+G_y[x,y]^2} \quad (4)$$

Gradient direction: $$\theta[x,y]=\arctan\left(\frac{G_x[x,y]}{G_y[x,y]}\right) \quad (5)$$

C. Non-Maximum Suppression

Adopt non-maximum suppression method to reserve the local gradient maximum value, and thinning roof of the gradient magnitude image results [12]. In each pixel, compare the center pixel of 3x3 neighborhood and two pixels along the gradient direction. Find the local maximum in the image gradient, and save the point of local maximum amplitude, at the same time set the point of non-local maxima to 0.

D. Dual-Threshold Extraction

After non-maximum suppression use dual-threshold extraction to process image, can eliminate false edges and connect discontinuous edges. Through giving the high threshold coefficient, low threshold coefficient and image histogram, separately calculate the high threshold and the low threshold. After non-maximum suppression, if the gradient of edge point is greater than the high threshold save it as the edge point. And if the gradient of edge point is greater than the low threshold delete it. The gradient between the values of two thresholds, and judge the point adjacent to the edge point whether exist the edge pixels greater than the high threshold in its eight-neighbors. If exist, save it as the edge point, or delete it.

E. Demerits of Traditional Canny Operator

In real application, Canny superior to more than 10 kinds of edge detection algorithms: Robert, Sobel, Laplace etc, but Canny operator also exist following problems [13]:

- Impulse noise suppression effect of Gaussian filter is very poor, impact noise may be incorrectly detected as edges.
- Smoothing parameter σ, high threshold and low threshold determine the performance and quality of Canny operator algorithm, and these three parameters need manual set. It is very difficult to balance various requirements such as image denoising, keeping edges and details, false edges and adaptability, etc.
- Determine whether the current pixel has maximum according to eight-neighbors pixel gradient values may lead to the detect edges not precise enough. Further effect the edge connection through the dual-threshold value.
- The edge pixels are not up to a single pixel level, sometimes a edge point appears multiple responses.

III. Improved Canny Edge Detection Algorithm

By the analysis of the traditional Canny operator's shortcomings, it is necessary to improve the traditional Canny operator, the steps are as shown in Fig. 2.

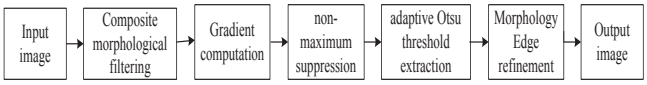


Figure 2. The process of improved Canny edge detection in this pepper

A. Composite Morphological Filtering

Adopt linear filtering method to suppress complex background noise of remote sensing image, but can't get a good result. Must use a non-linear filter methods. In recent years, mathematical morphological filtering becomes an important method of non-linear filtering methods, and it is widely used in shape recognition, edge detection, texture analysis, image restoration and enhancement, etc.

Grayscale morphology including erosion, dilation, opening and closed operations. Suppose F(x,y) for grayscale images, and B(s,t) for morphological structure elements. Grayscale morphological operations are defined as follows:

dilation operation: $$F\oplus B=\max\{F(x-s,y-t)+B(s,t)\} \quad (6)$$

erosion operation: $$F\Theta B=\min\{F(x+s,y+t)-B(s,t)\} \quad (7)$$

opening operation: $$F\circ B=(F\Theta B)\oplus B \quad (8)$$

closed operation: $$F\bullet B=(F\oplus B)\Theta B \quad (9)$$

Utilize opening and erosion operation of morphology filtering can not only inhibit burr noise and bridge noise, but also can smooth the boundary points of the image edge. Utilize closed and dilation operation of morphology filtering can not only inhibit small hole noise and crack noise, but also can smooth the outer boundary points of the image edge.

In this paper, adoptive an improved mathematical morphology filtering to balance contradictions between slipperiness and approximation. Using composite morphological filtering can smooth image effective , and can get an accurate image contour. Its formula is expressed as:

$$F=\frac{1}{2}\left[(I\bullet S\oplus S+(I\circ S)\Theta S)\right] \quad (10)$$

Among in equation above: I and S are the appropriate structure elements, F is edge of the image.

Improved Canny operator using composite morphological filtering operator to smooth denoising [14], and eliminate the maximum noise point. Get more precise the extreme points of the roof near the edge of the image, so as to obtain exact boundary connections. By filtering all the noise of specific structural elements can be filtered only once, and will not be repeated to produce new noise, ensures that the image structure will not be passivated.

B. Calculate Thresholds through Otsu Methos

In traditional Canny operator high and low thresholds need to be manually setting, cannot be determined according to the characteristics of different images. In view of this shortcoming, this paper use Otsu method obtain the threshold automatically [15]. Classic Otsu threshold algorithm uses threshold to divided image pixels into two categories, by the maximal variance between-class of dividing two categories to determine the optimal threshold value.

Mark T for the threshold of foreground and background, w_0 for proportion of foreground points and image points, u_0 for average gray, w_1 for proportion of background points and image points, u_1 for average gray. The total average gray of image is:

$$u_T = w_0 \times u_0 + w_1 \times u_1 \tag{11}$$

The variance of foreground and background is:

$$\sigma^2 (T) = w_0 \times (u_0 - u_T)^2 + w_1 \times (u_1 - u_T)^2 \tag{12}$$

Using traversal method to calculate threshold T which made σ^2 maximum, and the difference between foreground and background is greatest, on this T is the best threshold. Double gradient threshold of Canny operator is a threshold too. Here we select $T_{high} = T$, $T_{low} = 0.5T$. By analyzing the selection principle and gradient histogram of T_{high} and T_{low}, it is feasible to select T_{high} by Otsu algorithm [1].

C. Detail Edge through Morphological Structure Elements

Extract of image edge through Canny operator can achieve good results, but cannot achieve pixel-level, especially appear one-to-many response at the edge of the corner point. To obtain single-pixel-precision edge, this article phase in mathematical morphological algorithm for edge thinning [11].

The theory of using morphology algorithm to refine edge is: Make sure axle wire at the center of the image edge, and remain edge features, connectivity, direction. Refine the edge pixels of the image, makes the final output the single pixel of image edges, and get good stability.

IV. Experimental Results and Analysis

Experiments show that the effect of improved Canny operator superior to traditional Canny operator. Take traditional and improved Canny operator to get the image edge of Lena image, remote sensing images of ship and road [14], [16]. Experimental results are shown in Fig. 3-Fig. 6.

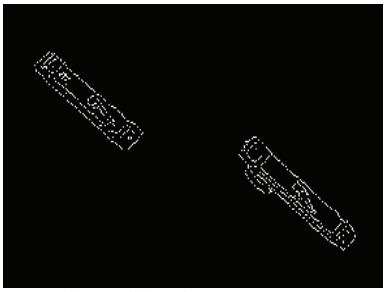
(a) Original image

(b) Traditional Canny operator

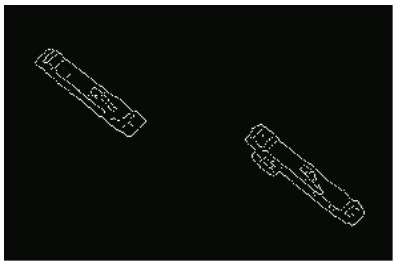
(c) Improved Canny operator

Figure 3. Comparison of Lena image experimental results

(a) Original image



(b) Traditional Canny operator

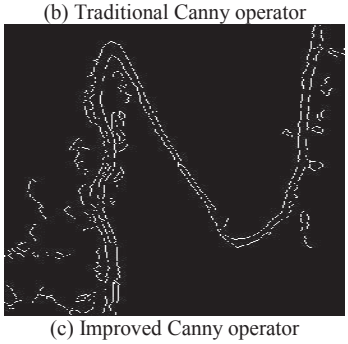


(c) Improved Canny operator

Figure 4. Comparison of ship image experimental results

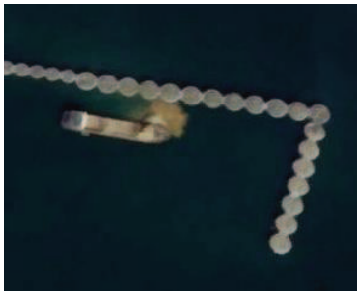
(a) Original image

(b) Traditional Canny operator

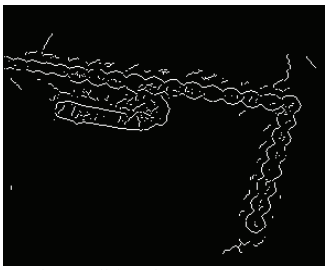


(c) Improved Canny operator

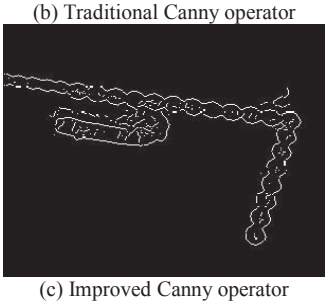
Figure 5. Comparison of road image experimental results



(a) Original image



(b) Traditional Canny operator



(c) Improved Canny operator

Figure 6. Comparison of port image experimental results

The thresholds of traditional Canny operator needs manually set, it is apparent that the image edges have many missing details, and incomplete. Using improved Canny operator throng composite morphological filtering to get better smoothing effect. Adopt Otsu method to set threshold, can detect the edge details of the image better, while maintain the edge clear and continuous. Detectable edges by morphological thinning have single-pixel-precision edge. From the detect results of port and road remote sensing images we can see improved Canny operator are more effectively reduce the effects of noise, detect more real edge, edge positioning more accuracy, and made the details better.

V. SUMMARY

In this pepper, we have improved the traditional Canny operator based on it's disadvantages, such as the threshold need to manually set and the edge details can easily loss. Using complex mathematical morphological filtering instead of Gaussian filter can get better noise smoothing effect, and preserve more details. Using Otsu method to set the high and low threshold adaptively, and avoid the limitations of manually setted thresholds. The experimental results show that the improved Canny operator is better than traditional Canny operator in some respects, such as smooth denoising, detail edges detection and edge continuity, so it has a good practical value.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support provided by the Natural Sciences Foundation of China (No.51207016).

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