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DESIGN TECHNIQUES FOR IMPROVEMENT OF CANNY EDGE DETECTION ALGORITHM

[1]Shwetha.V, [2]Dr.C.H.Renu Madhavi

Research Scholar,Associate Professor

Department of Electronics and Instrumentation Engineering
R V College of Engineering, Bengaluru,Karnataka,India

Abstract- Edge detection is a process of identifying and detecting sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity gray level value. Although a number of various techniques for detection of edges are available, but amongst all these edge detection techniques, the canny edge detection algorithm is the best, most effective and the widely used method for edge detection because it consists of a number of adjustable parameters which can affect the speed and effectiveness of the algorithm.We address two practical issues, namely smoothing factor selection and efficient implementation of thresholding in implementing Canny edge detection algorithm. Detecting the accurate edges or boundaries ease the location of objects in the image and parameters like shape, area can be measured easily. This paper presents a brief study on improved versions of canny edge detection. This paper contributes to present existing novel approaches to improve detection using canny edge detection.

Keywords – Canny edge detection,Thresholding,Smoothing factor

I. INTRODUCTION

Image segmentation is the process of breaking the images into meaningful parts so that no information is lost and helps to get more data, present in the image. Segmenting the image properly is a challenging task and utmost care is to be taken. Segmentation of the image can be done by the following approaches based on the discontinuity, based on the intensity value and based on the region of similarity.

Segmenting an image based on discontinuity, is often called as edge detection, is the key point. If the image contains two or more objects, certainly there will be boundary between those objects. This boundary leads to formation of edges and thus helps to cut the image based on these edges i.e. an edge occurs due to the discontinuity in the image intensity.

A significant change, usually the intensity, local to the image results in edges in the images. Edge detection is a necessary step in image processing, because the edges in images are the resultant of the boundary established between two objects or between an object and background. By detecting these edges, it is possible to divide the image into segment of meaningful objects. Edges in the image are detected by the first derivative and second derivative of the image intensity function. The traditional edge detection algorithms are done through detecting the maximum value of the first derivative or zero crossing of the second derivative.The fundamental steps in edge detection are:

i)Image smoothing for noise reduction: Noise in the image will affect considerably the first and second derivatives of the intensity. Hence noise must be filtered.

ii)Detection of edges: A local operation that selects all the ‘possible’ edges in the image.

iii)Edge localization: Selecting the true edges from the list of the ‘possible’ edges.

Edge detection is one of the most important techniques that have been commonly implemented in image processing. It is used in image segmentation, registration and identification of image processing. The concept of the edge in an image is the most fundamental feature of the image because the edge contains valuable information about the internal objects inside image. Hence, edge detection is one of the key research works in image processing. Edge detection of an image is a very important step towards understanding image features. The conventional edge detection operators, such as Roberts, Sobel[5], Prewitt, Kirsch, LOG and canny etc, obtain unsatisfying outcome in practice because of their drawbacks.In 1986, John Canny proposed the three performance criteria of optimal edge detection operator and had deduced an approximate implementation of the optimal edge detection operator—Canny operator[1]. Canny operator has been mostly put into practice because of its excellent performance[3].

II. TRADITIONAL CANNY EDGE DETECTION

In [1], John Canny thought an optimal edge detection operator should meet the following three performance criteria:

1) Maximum of signal-noise ratio (good detection), that is to say, there should be a low probability of failing to mark real edge points, and low probability of falsely marking non edge points. This criterion makes the output signal-noise ratio of the edge maximum.

2) Good localization, that is to say, the points marked as edge points by the operator should be as close as possible to the center of true edge.

3) Only one response to a single edge, that is to say, only one response output for a single edge, and the faint edges should be suppressed greatest.

In the procedure of edge detection, noise suppression and edge accurate locations cannot meet the requirements simultaneously. While the edge detection operator smoothes the image to remove the noise, the uncertainty of the edge increases. In contrast, when the sensitivity of edge detection increases, the noise does. Canny operator has made a tradeoff between the noise suppression and good localization [14], and deduced an approximate implementation of the optimal edge detector. The implemented steps as follows:

1) Smooth the image with Gaussian filter

Canny operator, firstly, smoothes the original image with the 1st derivation of 2-D Gaussian function [21], and obtains the smoothed image g(x, y). Assuming the 2-D Gaussian function as:

$$G(x,y) = \frac{1}{2\pi\sigma}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad (1.1)$$

Where σ indicates the standard variance of Gaussian function, and it determines the width of the Gaussian filter and outcome of smoothing.

2) Compute the gradient magnitude and direction of the smoothed image[22]

Computing the data array of smoothed image with the means of finite difference in the neighborhood of 2×2, denoting the partial derivation of the x-direction and y-direction as G(x), G(y), then its gradient magnitude and direction can be computed respectively:

$$M[i,j] \quad \sqrt{G(x)^2 + G(y)^2} \quad (1.2)$$

$$Q[i, j] = \arctan(G(y)/G(x)) \quad (1.3)$$

3) Perform non-maximum suppression and determine the candidate edge points

In the image of gradient magnitude, it produces the multi-points appearance surrounding the point M [i, j],which should be thinned to obtain the accurate positions by the means of single pixel. Namely, the procedure of this is called non-maximum suppression. During the processing, the canny operator performs the interpolation along its gradient direction surrounding its 8 neighborhoods, and then the center pixel M [I, j] is compared with its adjacent two pixels along its gradient direction. If it is less than any of the two, it is marked as 0; otherwise, it is marked as 1. When finishing this procedure, the multi-points are thinned as one pixel width, and the accurate gradient magnitude is preserved [12].

4) Perform edge detection and edge connection with double thresholds

Canny operator produces the final edge from the candidate edge points with double thresholds[15]. Firstly, it selects the high threshold Th and the low threshold Tl ;Secondly, it scans the whole image to detect any pixels that are marked as candidate edge points. If the gradient magnitude G(i,j) of Point(i, j) is greater than the high threshold Th, then it is absolutely determined as edge point.It is completely not edge point when the gradient magnitude G(i,j) of point(i,j) is less than Tl. For these points whose gradient magnitudes range from Tl to Th, they are considered as the suspected edge points and examine their connectivity. If their adjacent pixels have edge pixels, then they are also considered as edge pixels, otherwise, they are non-edge pixels. [13]

III. The drawback analysis of the traditional Canny operator[32]

Canny operator, although, is deduced based on the optimization theory[23], in practice, it does not often presents optimally. Firstly, this operator smoothes the image with Gaussian filter, which has also smoothed the high frequency signals that may have the edge pixels present, making the loss of edge information while suppressing the noise. In addition to that, it uses two thresholds called the high and low thresholds. The high and low thresholds are set manually requiring prior empirical knowledge, and it is possible to get a proper threshold after many experiments[28]. As with any recursive procedure, this process needs to use much stack space to store the intermediate data in order to be able to retrace. For large images, this may require a large amount of memory. For small memory systems, it puts unnecessarily tight restrictions on the image size that can be processed. For virtual memory systems, this may incur excessive virtual memory swapping and greatly prolong the running time. However, in practice, the high and low thresholds often change because of the scenes and illumination change frequently. The conventional canny operator lack of the capability of self-adaptation, in many cases, it cannot obtain a satisfying detection results.

IV. Addressing Issues Of Traditional Canny Operator

A.Edge preserving and noise suppression

To address the issue of edge preserving and noise suppression, different techniques have been introduced by various researchers which include replacing Gaussian filter with LOG filter,media filtering,bilateral filtering,self adaptive filter,anisotropic filter,Self adaptive filter or morphological filter.Some researchers also proposed different methods to overcome the problem of edge preserving and suppression of noise such as quad edge detection method,adaptive canny edge detection method,canny edge based image expansion algorithm, Modified Eight-Directional Canny for Robust Edge Detection method, DGW-Canny edge detector, noise-resilient edge detection algorithm.

B.Threshold Selection

The problem of threshold selection can be avoided by using various methods such as OTSU algorithm[41], customized threshold function, self-adaptive threshold value, connected component analysis algorithm, genetic algorithm, two adaptive thresholds were obtained by doing differential operation on amplitude gradient histogram, adaptive threshold selection method, adaptive dual-threshold detection, DGW-Canny edge detector.Many researchers have used OTSU method.It is because of the ease of implementation and relative complexity.

V.THE SURVEY ON THE PERFORMANCE OF DIFFERENT TECHNIQUES USED IN CANNY EDGE DETECTION ALGORITHM

Table 5.1: the survey on the performance of different techniques used in canny edge detection algorithm

Ref	Year	Design Methodology and Existing study	Inferences
[2]	2018	LoG filer was introduced as the first step of improved Canny algorithm. Also, gradient magnitude and kernel gradient were adjusted specially for edge detection in brain MRI images.	Various MRI images of brain tumor were used for testing. The results have shown that the proposed algorithm can recognize more details, which can help a lot in detecting the type of brain tumor.
[6]	2017	Firstly, the media filtering and filtering based on the method of Euclidean distance are adopted to process it; secondly using the Freichen 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.	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
[8]	2012	It has proposed an adaptive threshold edge detection algorithm in this paper, which applies the bilateral filtering that has the advantages of edge-preserving and noise removing firstly. Then it uses OTSU, which is based on gradient magnitude to maximize the separability of the resultant classes, to determine the low and high thresholds of the canny operator. Finally, the edge detection and connection are performed.	The experimental results show that this improved algorithm can well solve the drawback analyzed above, as well as, it have the capability of self-adapting the changes of scenes and illumination, and extended its use.
[9]	2014	Methodology is divided in two parts: a. Proposed Quad Edge Detection method, working algorithm using four convolution masks. First one for horizontal, second one for vertical, third one for positive left diagonal, and fourth one for positive right diagonal b. Proposed Enhanced Edge Detection method, working algorithm using six convolution masks The additional convolution masks are negative left diagonal and Negative right diagonal.	Experiment results have demonstrated that the enhanced and quad proposed methods for edge detection produces satisfactory results for different gray level images more than canny. And the enhanced Edge Detection method finding the edges of images with greater efficiency when compared with quad and canny methods. However, this method takes longer time to compute results due to its higher degree of complexity.
[11]	2017	This paper proposed a mobile application to detect cracks in the road and with customized threshold function in the requests to produce useful and accurate edge detection.	The Canny algorithm applied to a mobile application can be used to detect damage on the road very well with accurate results, but also by adding threshold function to the image can know the cracks the image more precisely because it will eliminate the smaller edge of pixel intensity of the edge pixel image that had crack.
[24]	2014	This paper proposes an optimized Canny edge detection algorithm for edge detection of core image by combining self-adaption smooth filtering and self-adaptive threshold value.	The final experiment results showed that the improved algorithm could retain weaker boundary and reflect the details of core crack, particles, and pore distribution more clearly. The detection results could provide more abundant information and were beneficial in explaining rock data compared with the traditional canny edge detection algorithm.
[32]	2000	The smoothing factor of the Gaussian kernel should be chosen to maximize the discrete version of Canny's original criteria.Thresholding with hysteresis should be implemented using an efficient connected component analysis algorithm.	Following the suggestions in implementing Canny's edge detector will in general result in optimal edge detection quality and very significant reduction in running time for large images.
[33]	2007	For contour detection, this paper proposed the improved template algorithm, which is not only including the gradient directions of X and Y, but also the first order partial finite	The proposed algorithm is an effective, real-time detection algorithm. Experiments showed that this improved CANNY algorithm has better noise suppression and edge continuity.

		differences of directions 45 and 135 degree in calculating the amplitude values. These mostly improved the calculation accuracy of the amplitude values. In the non-maxima suppression process, the factor ratio of four quadrants of linear interpolation is improved to achieve better detection results.	
[34]	2009	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 achieve the refining treatment of edge points detection and the single pixel level 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.
[35]	2016	Firstly, anisotropic filter to denoise original grayscale images is used This method can effectively suppress noise and preserve the edge feature. Secondly, the paper searches optimizing high and low thresholds used in Canny operator utilizing genetic algorithm based on the Otsu evaluative function to avoid human factors	Experiment results show that, the detection results of this method have advantages of smooth and dedicate edge character, high precision, self-adaption and so on. Number of false edges has been reduced, and simultaneously the missing detection of real edges is also decreased. Therefore, the algorithm in this article has certain robustness and is worthy of being promoted
[26]	2012	In this paper,a method is introduced that computes the threshold values from the foreground and background image pixels.An image is divided into several blocks using at multiple resolution levels.After that,a sampling approach is used on global and local regions to get the optimum thresholds by selecting the highest between the class variance values	The proposed method outperforms the traditional canny method
[25]	2013	An adaptive Canny edge detection method is proposed which based on Canny theory.Adopt the 3*3 neighborhood instead of Canny algorithm in 2*2 neighborhood to calculate the calculation gradient. Then, the maximum between-class variance (Otsu) method is used to obtain the high and low thresholds.	The improved algorithm can suppress noise on edge detection and preserve the edge information, detection with high precision.
[40]	2010	The paper mainly uses the Mallat wavelet transform to reinforce the weak edge of input images, quadratic optimization of genetic algorithm to get a proper threshold in self-adapting standard during Canny algorithm steps. With the base of Canny operator and the improvement, the paper builds a new model, which satisfies the need of pavement edge detection real-time	Computer simulations show that the improved algorithm can make up for the disadvantages of Canny algorithm, detect edges of pavement images effectively, and is a less time-consuming process.Particularly, it has been shown that the presented algorithm can not only eliminate noises effectively but also protect unclear edges.
[38]	2017	In this paper, an improvement of the Canny edge-based image expansion algorithm is proposed.In this method, two cases according to the orientations of the edges are defined. In any diagonal orientation, two new operators determine whether the diagonal direction is the left or right diagonal. For different cases, different functions are proposed to process the neighborhood pixel values of the edges.	The new expansion algorithm preserves the edges of an object. It generates the higher contrast and sharper images through modification of the neighborhood pixel values of the edges
[39]	2010	The Otsu method is one of the most popular self-adaptive threshold algorithms. However the Otsu method cannot automatically set the low threshold according to the different image intensity adaptively. In order to overcome this defect, an adaptive threshold algorithm for the Canny Operator was	The experiment results shows that the improved self-adaptive threshold Canny Operator can detect reasonable number of true edges while detect less fake edges and textures. Thus, the self-adaptive threshold Canny Operator has the better performance on edge detection. In addition,

		proposed which calculated the low threshold adaptively based on a probability model.	the time consumption of this algorithm is even less than traditional methods.
[37]	2015	This paper adopts the method of combining global with local edge detection to extract edge. The global edge detection can obtain the whole edge, which uses adaptive smooth filter algorithm based on Canny operator. Local edge detection which uses distance weighted average method based on k-average method can overcome the impact of outliers on clustering effectively. Complete skull image edge is got through edge detection method that combines global with local.	The simulation experiments show that the algorithm can extract fully skull image edge whose detail is richer, positioning is more accurate, and it is not affected by noise easily.
[36]	2017	This paper proposed an improved method on Canny algorithm. Two adaptive thresholds were obtained by doing differential operation on amplitude gradient histogram. Then we connected edge points to get some generalized chains. After that, it needed to calculate their mean value to delete generalized chains, which are smaller than the mean value. Finally, the image edge detection results were got by linear fitting method.	The improved algorithm not only has the advantages of the Canny algorithm, but also improves the anti-noise ability, and keeps the edge image more clearly.
[31]	2015	An adaptive threshold selection method is proposed that estimate the high and low thresholds of the entire image while only processing the pixels of an each block. In this paper, the threshold segmentation based approach is developed to improve performance of distributed canny edge detector.	The theoretical analysis shows that threshold segmentation can upgrade the edge detection accuracy. The high and low threshold of image can vary in adaptive manner according to the context contained in the image. The use of small size structural operator responses to precise edge structures with reduction in noise level.
[30]	2014	This article presents an edge detection mechanism,named as Modified Eight-Directional Canny for Robust Edge Detection (MEDC) which is a modification of Canny's method. This technique has an add-in feature of performing edge detection in eight directions, by partitioning the two dimensional image space into eight planes in the order of 22.50. This feature enables MEDC to detect almost all the edges of a given image.	This method was tested on many textured-images and was found that it has produced better results.It is proven that MEDC performs better than Canny, on most of the test images.
[29]	2014	This paper proposed an improved algorithm based on Canny algorithm.This algorithm introduced the concept of gravitational field intensity to replace image gradient, and obtained the gravitational field intensity operator. Two adaptive threshold selection methods based on the mean of image gradient magnitude and standard deviation were put forward for two kinds of typical images (one has less edge information, and the other has rich edge information) respectively	The improved algorithm not only keeps the advantages of the traditional Canny algorithm, but also it enhances the ability of noise suppression and keeps more edge information, i.e. it has higher SNR. This algorithm can obtain threshold automatically, which has higher practical value in the practical engineering application
[27]	2018	In this paper, a method is introduced that computes the threshold values from the foreground and background image pixels from global and local image analysis. According to this method, an image is divided into several blocks using multiple resolution levels.After that, a modification sampling approach is used on global and local regions to get the optimal thresholds by selecting the highest between the class variance values.	The results show that from the four type different image datasets used, the proposed method outperforms the Canny method and previous work in terms of FOM values and the edge image results obtained. The result of the image shows the accurate edge image because it contains the edge image from the foreground and has ignored the edge image from the background.
[18]	2010	This paper select the Canny edge detection	The experiment show that,the improved

		operator, and improved it with filtering by Gauss sigma function and adaptive dual-threshold detection and nonlocal maximum suppression based on dual-threshold, apply to core image edge detection, can get good results both on the precision and accuracy of detection and edge thinning.	Canny algorithm increases the accuracy and immediacy of edge detecting while ensure simultaneous. After detected the core image with improved canny algorithm, engineers can be analyzing and statistical the core image data effectively.
[17]	2011	An improvised edge detection technique is proposed here. The technique uses a Laplacian of Gaussian gradient with a new approach towards the thresholding section. The DGW-Canny framework has been experimented on a data set of images categorized on the basis of vectors proposed here.	Results confirm that the DGW-canny edge detector, besides being insensitive to noise, is able to fabricate superior and accurate edges in regions of fine graining, geometrical figures and alphanumerics as compared to the current edge detection techniques.The detector is also able to handle noisy as well as noiseless images
[19]	2011	A self-adaptive canny operator was developed to detect edges of growing citrus images. RGB color images were obtained and linear transformed into R-B chromatic aberration space at first. In R-B space, width of Gaussian filter fast calculated using integral images and the high and low threshold values obtained by OTSU algorithm were extracted to improve automatic edge detection.	Experimental results show that this method can obtain proper parameters and it was less sensitive to lighting variations. Moreover, the method has very good performance in respect of the edge connectivity,integrity and weak edge detection.
[7]	2009	In this paper, a noise-resilient edge detection algorithm is introduced for brain MRI images.This algorithm includes Replacement of Gaussian smoothing kernel, modification of the gradient magnitude of Canny operator,modification of gradient kernel and fusion of edge images	Computer simulations show that the proposed algorithm is noise-resilient and able to edge-detect brain MRI images effectively in an impulsive noise environment. Also, it makes up for the disadvantages of Canny algorithm, and can detect more edges of MRI brain images effectively. Also, the concept of images fusion is utilized for effective edge detection
[4]	2018	In this paper, an improved adaptive Canny edge detection algorithm for infrared image of ship is proposed.The contrast limited adaptive histogram equalization algorithm is adopted to enhance the infrared image, the morphological filter replaces the Gauss filter to smooth the image, and the OTSU algorithm is utilized to adjust the high and low thresholds dynamically.	The experimental results show that the improved Canny edge detection algorithm can automatically set the thresholds, extract the edges, and reduce false edges. It is proved to be an effective method for edge detection with high accuracy and precision.
[2]	2018	In this paper an edge detection algorithm, specially adjusted for processing brain MRI images is presented. LoG filer was introduced as the first step of improved Canny algorithm. Also, gradient magnitude and kernel gradient were adjusted specially for edge detection in brain MRI images..	Various MRI images of brain tumor were used for testing. The results have shown that the proposed algorithm can recognize more details, which can help a lot in detecting the type of brain tumor.
[16]	2009	On the basis of analyzing the conventional Canny algorithm, this paper advanced an adaptive edge-detection method based on the canny operator. This method not only keeps the Canny's good performance in good detection, good localization and only one response to a single edge, but also improves the capability of restraining the fake edge and the automaticity of edge-detection based on the Otsu's thresholding method.	The result indicates that edge contours got from this method have fine SNR and Connectivity,and the most important is that it can self-adaptively ensure the high and low threshold according to the characters of real images,so it has higher automatization. Now the results from the two methods only can be evaluated by eyes,and how to judge them impersonally is our direction to study thoroughly.
[10]	2013	An improved edge detection algorithm is proposed in this paper. The Gaussian filtering is replaced with the morphological filtering. Experimental results show that the improved Canny operator can filter the salt & pepper noise effectively, improve the accuracy of edge detection, and achieve an ideal effect of edge detection.	The final edge image can reduce effectively the influence of noise, keep the edge strength and more complete details, get a more satisfactory subjective result. And by using objective evaluation standards,compared with the traditional Canny operator, information entropy, average gradient, peak signal to noise ratio,correlation coefficient and the distortion

			degree also have increased significantly.
[20]	2010	An improved Canny edge detection algorithm based on predisposal method was presented in this paper, through gray value distance judgment and edge points' correlation coefficient comparison: two predisposal steps with the Canny operator processing, better edge images were got by the proposed method..	The result showed that the proposed method was much more reliable under the corruption of Gaussian noise environment

VI. CONCLUSION

Edge detection is one of the most important techniques that have been commonly implemented in image processing. Though Canny edge detection algorithm is the most efficient algorithm,it also has some diadvantages. In this paper,various techniques have been studied to overcome the disadvantage of traditional canny edge detection algorithm.It is found that the various modification done to the canny edge detection algorithm outperforms the traditional canny edge detection algorithm.

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