IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 8, August 2016

Edge Detection of an Image Using an Improved Canny Algorithm: A Review

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Abstract: Edge detection of an image is a fundamental, yet one of the most important fields in image processing, pattern recognition, and image analysis and computer vision technique. In edge detection, the structural information of an image is extract and reduced to important data to process. There are different methods for detecting the edge, and mainly categories into search based and zero-crossing based. One of the most common methods is 'Canny edge detector', and work well under some condition. Like every other method, it had some disadvantages, drawbacks and limitation. Due to this limitation and constant evolution of image processing, a better method is in demand and a number of researches had been done to improve the methods and the performance of this technique. To rectify the problem, and to have a better outcome, a new method of edge detection is needed. To increase the performance of the detector, the removal of noise from an image is the first important thing such that it does not affect the detection by showing false noise. The detector must also have a single response of thin line for each detected edge. In other words it must present clear and corrected image which might further be used for different purpose: medical field for identifying diseases, object identification and computer vision system etc.

Keywords: Edge detection, image processing, pattern recognition, computer vision technique, Canny detector, 2-D Otsu's method, Threshold.

I. INTRODUCTION

What is an edge of an image? There are numbers of definition of edges which are based on image gradients, not on semantics. The definition itself can be differ based on task and can be said application dependent. A few definitions of edges are as follows

- "the gradient in one direction is high, while the gradient in the direction orthogonal to it is low".
- "an edge can be defined as a set of contiguous pixel positions where an abrupt change of intensity (gray or colour) values occur".
- "a pixel as edge if gradient is above a suitable threshold and some others within its selected surrounding area are similar as well".

The edges extracted from a two-dimensional image of a three- viewpoint dependent or viewpoint independent. A viewpoint dimensional scene can be classified as either independent edge typically reflects inherent properties of the three-dimensional objects, such as surface markings and surface shape. A viewpoint dependent edge may change as the viewpoint changes, and typically reflects the geometry of the scene, such as objects occluding one another.

Edge detection is the process of detecting of an edge of an image explains above. In edge detection, the structural properties of images are reduced to a few important data based on the need for processing. The main purpose of detection of edges of an image is to capture the important event and change in properties. This edges capture using edge detector are using in different image processing.

Edge detection methods are mainly categories into two groups, search based and zero crossing The search-based methods detect edges by first computing a measure of edge strength, usually a first-order derivative expression such as the gradient magnitude, and then searching for local directional maxima of the gradient magnitude using a computed estimate of the local orientation of the edge, usually the gradient direction. The zero-crossing based methods search for zero crossings in a second-order derivative expression computed from the image in order to find edges, usually the zero-crossings of the Laplacian or the zero-crossings of a non-linear differential expression. As a pre-processing step to edge detection, a smoothing stage, typically Gaussian smoothing, is almost always applied. The edge detection methods that have been published mainly differ in the types of smoothing filters that are applied and the way the measures of edge strength are computed. As many edge detection methods rely on the computation of image gradients, they also differ in the types of filter used for computing gradient estimates in the X-direction and y-directions.

There a different algorithm, logic and method used and develop to detect the edge of an image. These methods are developed in such a way that they perform for specific condition, or under specific noise influence. Most common edge detection algorithms include Sobel, Canny, Prewitt,

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Roberts, and fuzzy logic methods. In this paper, we will try to study the drawbacks, provide solutions, improved and implement better and noised resilient edge detection algorithm based on canny algorithm [1]. The algorithm developed by john canny to detect an edge of an image is a simple, yet effective algorithm with a huge room for improvement. The traditional canny detector is sensitive to impulse noise as the Gaussian filter is not best suited to filter those impulse noises. So in order to overcome that noise sensitivity, a new technique, better suited to high impulse noised is proposed in this paper.

Along with the proposed method to improve edge detection, comparison of the proposed method along with the previous method including the traditional canny method is put out in this paper. The rest of the paper is group, categorised and arrange in some of the following order: first, a brief review of research related to proposed approach is provided. Secondly, the review is followed by the proposed approach for effective, noise resilient and accurate edge detection. Third and lastly, based on the review of previous research along with the proposed method, conclusion is drawn.

II. CANNY DETECTOR

The traditional canny detector can be divided into four categories, Gaussian filter, Gradient Calculation, Non-maximum suppression, and hysteresis thresholding. These categories are briefly explained in the following.
To smooth the image and reduce the obvious noise, a Gaussian filter is applied to convolve with the image. The Gaussian function is given as:

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

The convoluted image may be given as:

$$f_1(x,y) = G(x,y) * f(x,y)$$

Where, f(x, y) is the original image, and 'σ' is the parameter of Gaussian filter which control the degree of denoising.
After convoluting an image with Gaussian function, the gradient magnitude and direction is calculated using the following formula:

$$G_x = (f_1(x+1,y) - f_1(x,y) + f_1(x+1,y+1) - f_1(x,y+1))/2$$

$$G_y = (f_1(x,y+1) - f_1(x,y) + f_1(x+1,y+1) - f_1(x+1,y))/2$$

Where, G_x and G_y are gradient magnitude in 'x' and 'y' direction respectively. Then, the gradient magnitude G and gradient direction θ is calculated using the following equation.

$$G = \sqrt{G_x^2 + G_y^2}$$

$$\theta = \text{atan2}(G_y, G_x)$$

From the gradient direction and magnitude calculated from above, non-maximum suppression which is used to thin the edge extracted from the image using gradient calculation. Edge extracted after gradient calculation is still thick and blurred, thus non-maxima suppression help to suppress all the gradient value to 0 except the local-maxima, which indicates the location with the sharpest change of intensity value. In this process, the gradient magnitude G(x, y) of the point (x, y) is not greater than the two of adjacent interpolation in the direction of Θ(x, y), the point (x, y) will be marked as non-edge point, otherwise marked as edge point.

After Non-maximum suppression, the edge extracted are almost the real edge, but certain edge cause by noise are still present. To remove these unwanted edges, two threshold value is empirically assign such that if the edge pixel gradient is higher than the high threshold value, it is taken as the strong edge. If the gradient value of edge pixel is lower than the threshold value, the edge pixel is suppressed. If the edge pixel gradient value is between the two threshold value, it is taken as weak edges and is compared with its neighbouring pixel. If the pixel is connected with a strong edge then it is taken as a true edge. Fig 1. Shows the performance of traditional canny in noise and noiseless environment.

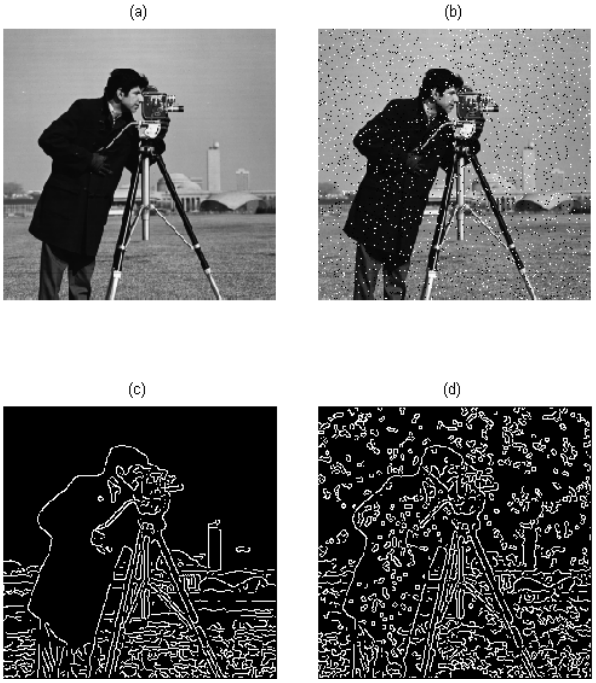

Fig (a) Original image (b) Noisy (5% salt & pepper noise) (c) Edge (Original Image) (d) Edge (Noisy Image)

III. LITERATURE SURVEY

Several researches have been done under edge detection, including performance comparison of various techniques along with improvement on each technique to overcome its limitation. There are many limitation in edge detecting

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technique mostly influence by noise, resulting in detection of false edges, smoothing of edge of real image along with the noise etc. Also gradient and direction calculation is influenced by noise. The other important factor is thinning of an edge.

From various comparisons done among basic methods, Srinivas, hemalatha and jeevan K.A[2]conclude based on their research that among Sobel, Robert's, Prewitt, kirsch's, LoG, Canny, Marr-Hildreth edge detection method, the first three produced result that are deviated from the original image. While the other four produced fine edge in the absence of noise.

On further studies and comparing with K-means edge detection, Anu Sharma and Gulista[3] point out the drawback of both techniques. In canny edge detection, the adjustable parameters can affect the performance time and efficiency while in K-means value detection; the K-value which is manually set could cause the same problem with canny detector.

Another comparison is also done between canny and mathematical morphological technique by A.V Kavitha, Madhulika Y and Siddardha[4] stating that Canny detection produce thin edge while mathematical morphology works well under influence of salt and pepper noise. Taking above studies and comparison, it is clear and save to states that each detection method had its own advantages and disadvantages. Also, among various methods, canny detection method is one of the most popular and commonly used.

To overcome the disadvantage and short coming of Canny method, number of researchers have put their thought in improving the technique to produce better result even under influence of noise and low lit image. To address the issue in canny detection such as over smoothing of image by Gaussian filter, or fail to remove salt & pepper noise by the filter, influence of noise in gradient calculation, complications and complexity regarding assignment of thresholds value and failure to achieve high and satisfactory accuracy of single response for edge-multi point response, several improvement have been made. A brief review of changes on the ground of improvement of canny will be discussed in this section.

According to John Canny, there are three important criteria for effective edge detection, these are:-

- High SNR criteria: Focus on good detection result which makes the probability of missing true edge and false detection non-edge as small as possible
- High positioning accuracy criterion: Distance of the detected edge point is the nearest which makes edge positioning accuracy highest
- Single-edge response criterion: Has only one response to single edge point maximally inhibit the occurrence of pseudo edge.

Based on these criteria, numbers of method and technique have been developed and studies for different purpose and different field. Yidong Bao an Dongmei[5] Wu believe and state from their studies that the effectiveness of traditional canny edge detection algorithm is highly degraded by its weak effect in reduction of salt and pepper noise and complicated by manual assignment of threshold value. And came up with a solution that it can be improved by changing Gaussian filter with Gaussian weighted median filter and finding effective threshold value using Otsu algorithm. First, they replaced Gaussian filter with median filter which is more suitable to remove salt and pepper noise without smoothening the edge of an image. Then they used Otsu self-adapting algorithm to calculate the threshold value giving an overall good edge detecting algorithm.

Lin Zhang[6] however approaches a little differently by introducing different filter along with different method to select the threshold value. For filtering the noise, he used wavelet transformation technique called multi-wavelet adaptive denoising to remove unwanted speckled noise and for thresholding, the upper and lower threshold are assign based on mean values of gradient of entire image to adaptively select the value.

To effectively detect the depth edge of a 3-D model, S.M. Abid Hasan and Kwanghee Ko[7] modified the traditional canny to produce better result. First, changes is made in the filter by replacing Gaussian filter with median filter which work better for removing Salt & Pepper noise. And then the edge detection process is replaced by morphological approach in which morphological operators are introduced. In morphological operations, the key operators are erosion and dilation. The structuring elements place data at probable location and comparing with neighbouring pixels whether the element 'fits' the neighbourhood or 'hit' the intersection elements and create new binary image. The structuring elements are mainly binary image containing the value zero or one.

Yu Chen, Caixia deng and Xia Xia Chen[8] make a huge improvement tackling various shortcomings of traditional canny detector to get noise resilient, accurate and single edge response of an image. They believe that speed of processing the technique is important along with quality of result in edge detection. So, they segmented the image using Otsu algorithm and process the image for faster process. After splitting the image, removal of noise is done with hybrid-filter of adaptive median and mathematical morphology. Also they made changes in gradient calculation by taking first order partial derivative of 8-neighbour in contrast with 3-neighbour derivative in traditional canny. Then edges are extracted from each image then combine each Praneeth Ch, Srinivas Rao V, and Srinivas K[9] made an edge detector based on an adaptive median filter which has high capability to remove noise for certain value of salt and pepper noise. In their method, Gaussian filter is swap with an Adaptive median

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filter for better removal of noise and protection of edges of an image in traditional canny yielding high performance.

The detection method based on traditional canny operator can improve these shortcomings to large extent but even canny operator has its deficiency. At present, there are quite number of edge detection methods based on canny operator.

In literature [10], improvement canny operator edge detection algorithm basing on adaptive dual-threshold is proposed. Some technical applications related to other medical fields are derive from research on medical image detection technology. Segmentation of brain medical image is applied by Lubis[11] to detect disease. Asymmetric Gaussian function segmentation technology is defined by Haksoo[12] to test position and organizational characteristics of medical organs. Graphic segmentation and contour filling algorithm is utilized by El-said [13] to put forward a kind of 3D medical image segmentation technology, which uses feature vector of the smallest characteristic value to solve image segmentation problem. To sum it all, there are several numbers of edge detection methods and multiple technical applications in different fields. So there are no best methods or worst but some methods perform better than the other and some methods are better suited for some condition. We can conclude that we cannot choose one specific method for all fields but choose each method on the basis of each specific field and develop and improved those methods purely for that specific purpose.

IV. PERFORMANCE PARAMETER

This section describes the general performance parameter that will be used. To measure the ability to remove noise, MSE, SNR and PSNR will be calculated in the filter level of the algorithm, and these values will be calculated between the original image and the filtered image for each algorithm. Non-quantitative visual identification of the edge image for each method for overall performance of the method will also be done.

V. CONCLUSION

This work reviews on traditional canny edge detector algorithm and its improvement for detecting edge with better accuracy of an image under the influence of noise, single edge response for each edge of an image, and differentiate between the weak and strong or true edge which can be further implemented in different fields of image processing and real life application. In this work the main focus will be better noise removal technique to improve the performance of an edge detector under the influence of noise. The future work might include better removal of noise, better identification of edge based on intensity, and automatic adjustment of the algorithm for different noise and different noise density such that it can improve its real life application.

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