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An Adaptive Approach to Improve Canny Method for Edge Detection

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Abstract: ***Edge detection is the most important stages in digital image processing for all fields of applications. Out of many approaches for edge detection such as Sobel, Prewitt, Canny, Laplacian of Gaussian method and Robert, Canny approach is the best. Canny edge detector is widely used in computer vision and medical imaging to locate sharp intensity changes and to find object boundaries in an image. The Canny edge detection algorithm is most widely used edge detection algorithm because of its advantages, whereby it classifies a pixel as an edge if the gradient magnitude of the pixel is larger than those of pixels at both its sides in the direction of maximum intensity change. This paper presents an adaptive approach for improving Canny algorithm which uses an adaptive Gaussian filter to smoothen the noise and edges differently and employing variable sigma and threshold values for different parts of the image.***

Keywords: Segmentation, Edge, Edge Detection, Gaussian filter, Thresholding

1. Introduction

Segmentation refers to the task of extracting apart of an image or video frame, of interest for further processing [1], take an example in a computer vision application where by a palate number of a car has to be identified, we need to extract a particular camera video frame, segment the area containing number plate from the frame and then proceed with classification process, Segmentation is one of the most difficult tasks in image processing; segmentation should stop only when the object or region of interest in an application has been detected [1] Improving the probability of accurate segmentation determines the eventual success in computerized analysis process [1], In classification process , to identify letters and numbers by whatever classifier we intend to use no matter how optimal it is (not even a Bayes classifier), we need as clear edge as possible, even though perfect edges are not practical realizable[4], we can still improve the results of the Canny algorithm with the proposed approach in this work.

2. Problem Statement

Despite Canny method being the strong method for edge detection, it has the following major weaknesses, first, it uses Gaussian filter whish smoothen both noise and edge equally, that means with it there is a chance to miss the weak edges which are useful for correct estimation of the object boundaries and which can finally lead to wrong decision[2]. Secondly; Canny method uses the same sized filter width for entire image, that means the noise and edges will be smoothen by the same filter width, whilst if we need to achieve high accuracy detection we need more smooth effect to be added to noise and less to be added to the edge. These two problems create a research window to improve the algorithm.

3. Edge Detection

An *edge* is a significant, local change in image intensity [5], the simplest edge is the line separating uniform regions of different intensity. In practice we can not observe perfect (ideal edge due to noise on the image data, thus we only see gradual change in intensity from one region to the other [1], this is the key reason why we need to have an adaptive filter to reduce the noise before detecting the edges.

3.1 Steps in Edge Detection

All edge detection algorithms follow these steps to achieve their basic objective, first; image is converted to gray scale level, a color image is a multichannel signal and can be represented by three matrices (RGB), after conversion, we get a 2D image (luminant image) or a black and white image, this is represented as a single matrix [5], Second; image smoothing for noise reduction, Third; detection of edge points, this is a local operation that extracts from an image all the points that are the potential candidates to become edge points and lastly; edge localization , the objective of this step is to select from the candidate, edge points only the points that are true members of the set of point comprising an edge[3]. Canny method which myself I like to call it as a 'hybrid' method, it applies Gaussian filter to smooth the image in order to remove noise, applies non-maximum suppression to get rid of spurious response to edge detection, applies a double threshold to determine potential edges and lastly track edges by hysteresis to suppress all edges that are weak and not connected to strong edge [13]. The popularity of the Canny edge detector can be attributed to its optimality according to the three criteria of good detection, good localization, and single response to an edge. It also has a rather simple approximate implementation, which is the subject of this paper. figure 1 below illustrate RGB and grayscale images and figure 2 shows the basic steps in any edge detection algorithm.

(a) (b)

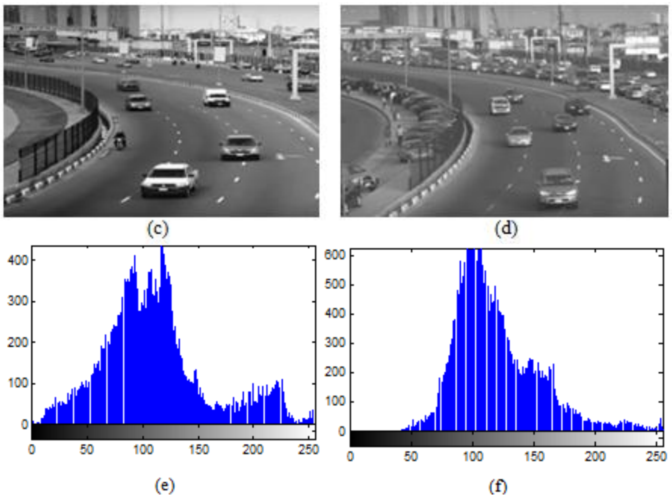

Figure 1: (a) and (b) RGB images extracted from [7], (c) and (d) are the corresponding grayscale images and (e) and (f) are the intensity distributions of (a) and (b) respectively

3.2 Gaussian Filter

The Gaussian function has important applications in many areas of mathematics, including image filtering. It can be used for smoothing images or detecting edges. An image is a 2-D image, which means to smoothen it we need to apply a 2-D Gaussian function, a 2-D Gaussian function is defined by equation (1) bellow

$$G(x,y)=\frac{1}{2\pi\sigma_0^2}e^{-\frac{x^2+y^2}{2\sigma_0^2}} \qquad (1)$$

Where by sigma (σ_0) basically controls how wide the Gaussian kernel function is going to be; higher sigma values blur over a wider radius. Since we are working with images, bigger sigma also forces us to use a larger kernel matrix to capture enough of the function's energy. This distribution is shown in figure 2 below.

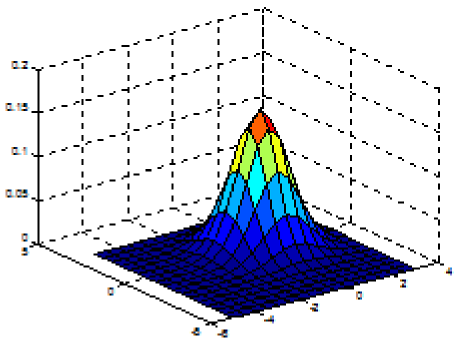

Figure 2: 2-D Gaussian distribution with mean (0,0) and σ_0 =1

Figure (3) below summarizes the steps performed by the ordinary canny method to calculate the gradient and finally the edge.

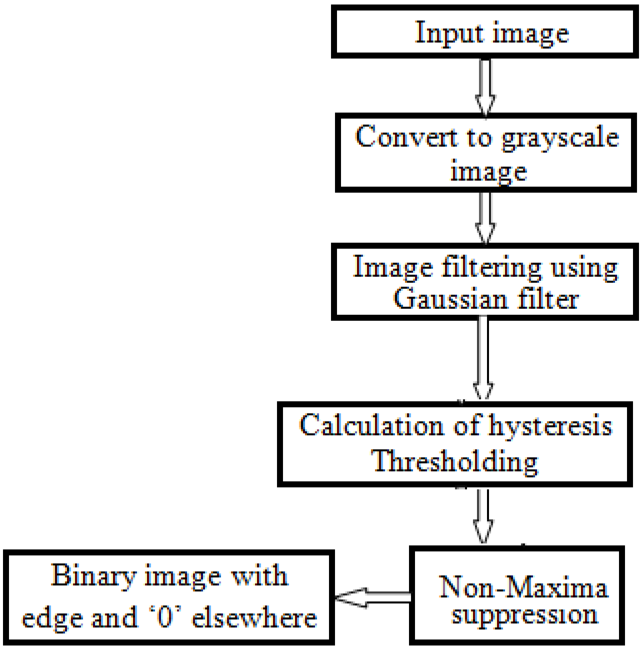

Figure 3: Steps in ordinary Canny edge detection

The image is convolved with the filter. The filter blurs the image to a degree specified by σ to minimize the effect of unwanted information [13. Figure 2 (b) is the output of a 5X5 Gaussian filter with σ=1.4 is shown in Equation (2) below

$$B=\frac{1}{159}\cdot\begin{bmatrix}2&4&5&4&2\\4&9&12&9&4\\5&12&15&12&5\\4&9&12&9&4\\2&4&5&4&2\end{bmatrix} \qquad (2)$$

4. Adaptive Filter to Replace Gaussian

As both edge and noise will be identified as high frequency signals, an ordinary Gaussian filter could add smooth effect on both of them, but to achieve high accuracy detection we need more smooth effect to be added noise and less to be added to the edge, Wang Bing[17] developed an adaptive filter, where the filter will evaluate discontinuity between grayscale values of each, the higher the discontinuity, the lower value is set for the filter at that point(this means that, this point is not a noise and we are particularly avoiding more effect on the edge or at the edge location) and the lower the discontinuity between grayscale values, the higher the weight value is set and this means that this point is an essentially a noise point

4.1 Pseudo code for MATLAB implementation of an adaptive filter

There are five steps we need to consider to successfully implement the above adaptive filter idea

Advantages and disadvantages of different Edge Detection Technique

1) Edge_start=1, sets the iteration up to the coefficient of the amplitude of the edge
2) Computer the gradient value at every pixel, from two partial derivatives

$g_x(x,y)$ And $g_y(x,y)$

3) We calculate the weight $w(x,y)$ at every point according to the formula

$$d(x,y)=\sqrt{g_x(x,y)^2+g_y(x,y)^2} \quad (3)$$

$$w(x,y)=\exp\left(-\frac{\sqrt{d(x,y)}}{2h^2}\right) \quad (4)$$

4) we define the adaptive filter as

$$f(x,y)=\frac{1}{N}\sum_{i=-1}^{1}\sum_{j=-1}^{1} f(x+i,y+j)w(x+i,y+j) \quad (5)$$

i and j being the row and column respectively, and we are interested in smoothing an image which is

$$N=\sum_{i=-1}^{1}\sum_{j=-1}^{1} w(x+i,y+j) \quad (6)$$

5) when edge_start=n after ∇ i,j then stop ,otherwise edge_start=edge_start+1 iterate again

Table 1: Advantages and disadvantages of different Edge Detection Technique

Edge detection operators	Advantages	Disadvantages
Robert	First order edge detection, used for image segmentation, Simplicity, less computation time,2*2 mask, responds to edges running at ±45°	High Sensitive to noise, not compatible for today's technology, inaccurate
Sobel	First order edge detection, used for image segmentation,3*3 mask, respond to edges running in vertical and horizontal direction	Computation time is high compare to Robert operator, less sensitive to noise compare to Robert operator
Prewitt	First order edge detection, used for image segmentation, Similar to sobel operator,3*3 mask ,smoothes edge region,	Suitable for noiseless image
Canny	Second order edge detection, used for image enhancement, Suitable for step edge, Smoothes noise ,non-sensitive to noise	High computation time, sensitive to weak edges, complex process

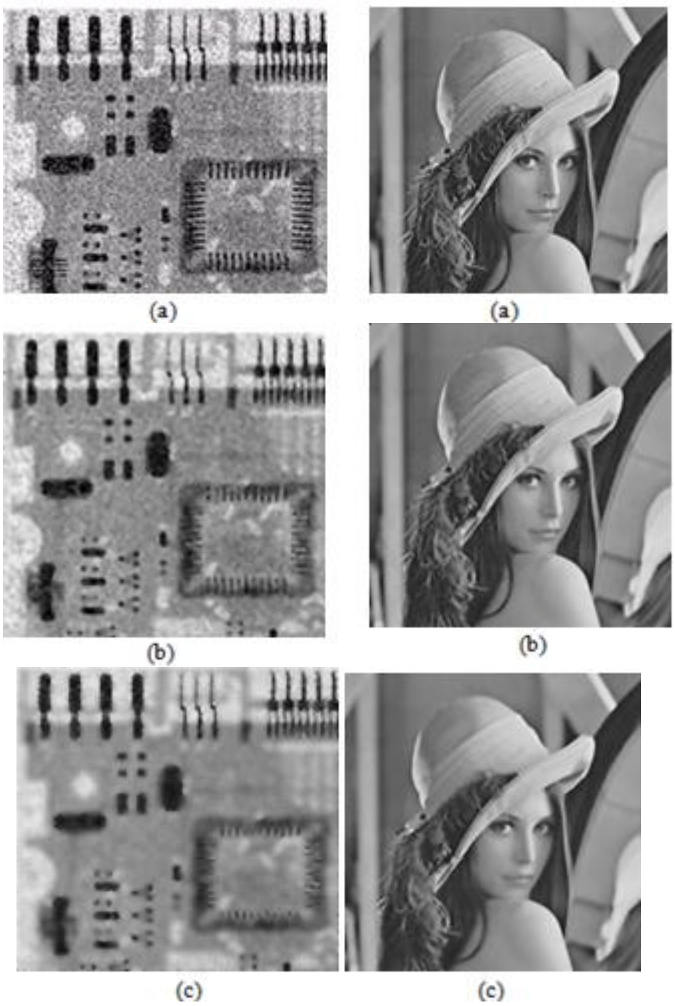

Figure 4: Shows the original image with noise (a), smoothen image using Gaussian filter (b) with a mask above (eqn 2) and the image smoothen by adaptive filter (c) discussed in section 4 above

5. Proposed Method

An easy but an effective approach is proposed in this paper in which different values of sigma and thresholding are applied in different parts of the image instead of processing the entire image with a single value of sigma and thresholding. In this method, image is divided into a number of sub-images. This number will determine the level of accuracy of the final output i.e. more number of sub-images will give better results the mean pixel value of each sub-image is calculated and depending upon these values each sub-image will be processed by adaptive filter with different sigma and thresholding values. It is quite evident that sub-images having very high or very low mean pixel values are likely to have faint edges while the ones with intermediate mean values are likely to have prominent edges. Therefore, the sub-images with higher or lower mean values are processed with small values of sigma and different thresholding

5.1 Pseudo code for MATLAB implementation of proposed algorithm

An image I; number of sub-images(N); sigma value (σ) assignment for a corresponding range of mean values
Output: a binary image of edges (E).
I(1,2,…N)←sub-images of I;
For I =1:N *Do*
N ← N+I(i);
Thresh ← N,
M(i) ← mean I(i);

σ ← f(M(i),N);
clean I(i)
reconstruction{I(1), I(2), ……..,I(N)};
Canny_modified(I);
End

For the purpose of testing results in this work , N=10 was used

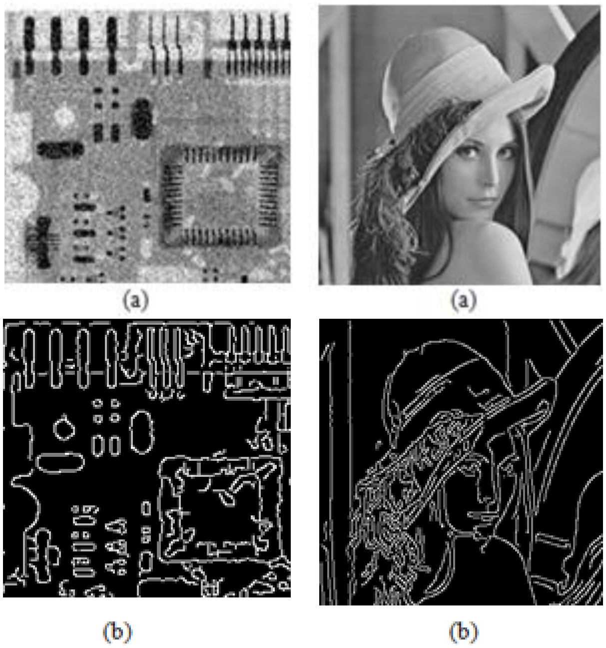

Figure 5: original image (a) ,edge by canny method(b)

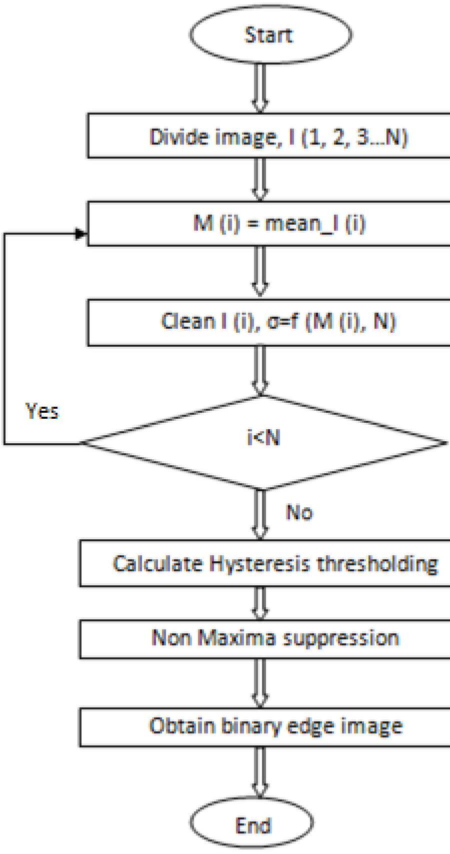

Figure 6: The flow chart of the proposed approach for the improvement

6. Experiment and Results Discussion

The proposed algorithm in section 5.1 was implemented in MATLAB and testing of the proposed algorithm has been done on a number of image of which two of them are shown in figure 7(c), results obtained by the original Canny edge detector are shown in figure 7(b) and better results were observed, as one can observe clear edges in figure 7(c) than on figure 7(b). From figure 7 stipulations it is evident that the proposed approach gives better results than the original algorithm. Here sigma is varied and other components e.g. Gaussian filter is replaced with an adaptive one discussed in section 4.

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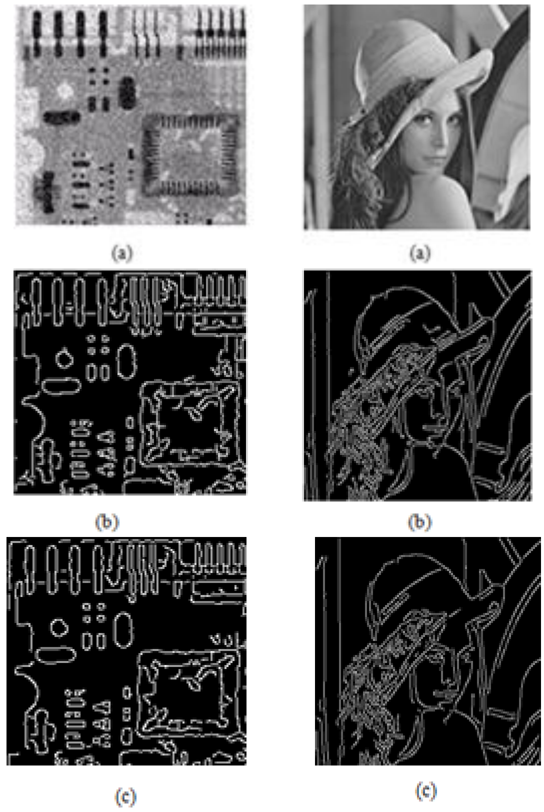

Figure 7: Original images (a), corresponding canny edges (b) and the corresponding edges obtained by proposed method (c)

8. Conclusion

In segmentation process carried out in industrial and medical image processing. Canny edge detector algorithm is considered as optimal edge detection technique but it responds to false image in noisy environment and is not adaptive in nature due to the reasons stipulated earlier. For a high resolution image, this new proposed algorithm performs better than traditional canny operator. In this paper, a proposed an adaptive approach for improving canny edge detection algorithm. The proposed approach has proved as an optimal edge detector due to due to good localization, detection and only one response to single response. The proposed approach involves a step that looks for further image evidence and connects short edge contours into longer ones and converts open contours into closed ones if image evidence supports that. In future the exact relationship between mean pixel value on edges and sigma may be found out.

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