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A Robust Method for Circle / Ellipse Extraction Based Canny Edge Detection

Adel A. Sewisy, Khaled F. Hussain, waleed F.Sammour

Abstract: *This article presents edge detection approach. There are several methods to determine the edge detection. This article will explain the Canny edge detection, their properties and when use them. The results of shape detection using canny edge approach is more accuracy than other method*

Keywords: *Edge detection, filter, convolution, Gaussian Filter, local maxima gradient magnitude.*

1. Background

As per the proposal made in this paper, in addition to the Hough based ellipse detection, the canny edge detection approach has also been implemented for line, circle and ellipse detection. This chapter mainly discusses the shape detection using enhanced canny edge detection. Here the optimization of canny edge algorithm with dual thresholding based Gaussian filter has also been discussed. The algorithm development and its implementation for shape detection is discussed in the following section of the presented manuscript.

2. Canny Edge Detector: An Introductory

Canny edge detector is one of the most efficient edge detection operators, which considers a multi-phase algorithmic paradigm for detecting huge range of edges in certain image of interest. Primarily, the step edge detection approach has been primarily employed for varied systems for image processing and computer vision technologies. These techniques do play very significant role for extracting significant structural information from varied visual objects and it reduces the data amount for swift processing and detection. There are certain criteria of an efficient canny edge based detection schemes. Some of these criteria are given as follows:

- The edge detection should be with minimal error representing that the edge detection must be accurate enough to detect as much edges as possible.
- The detected edge point from the operator must be precisely and efficiently localized on the center of the edge.
- Certain provided edge in the image under consideration must only be marked once, and in case of missing edges, the noise present in the image must not be creating false edges.

In order to fulfil these expectations, the scientist Canny in 1985 employed the scheme of calculus of variations that explores the function that ultimately enhances the given function. In fact the optimal function in canny edge detection scheme is presented by the sum of exponential terms, but it could be further approximated by the first derivative of a Gaussian. This is also the matter of fact that among varied developed schemes for edge detection, canny edge detection scheme is the most well defined and reliable detection approach.

In order to fulfil the above mentioned fundamental criteria for edge detection and for ease of implementation, this algorithm has been developed and enhanced that makes it most employable scheme for edge or shape detection. The overall process of Canny edge detection scheme can be presented in five consecutive phases. These are as follows:

- Implement Gaussian filter for smoothening of the image so as to eliminate the noise components
- Estimate the intensity gradients of the image under consideration.
- Implement the non-maximum suppression technique for eliminating issued of spurious response in efficient edge detection.
- Implement Dual Threshold based Gaussian filter for estimating the edges in the image.

- Perform the finalization of the edge detection by suppressing all the other edge components or edges detected which are weak and are not connected to any strong edges.

A brief discussion of the employed schemes for canny edge implementation for shape detection is given as follows:

3. Gaussian Filter

As all the edge detection techniques are significantly influenced by the noise components and therefore it becomes inevitable to remove the noise factor so as to avoid false detection. In order to perform smoothening of the image, a Gaussian filter is considered that significantly smooth the image so as to minimize the effects of noise factor edge detection. In this paper the Gaussian filter has been employed to achieve higher accuracy in shape detection.

The mathematical expression of a Gaussian filter kernel with the size of $2k + 1 * 2k + 1$ can be presented as follows:

$$H_{ij} = \frac{1}{2\pi\sigma^2} * exp\left(-\frac{(i-k-1)^2(j-k-1)^2}{2\sigma^2}\right)$$

Here, it should be noted that the selection of the size of the Gaussian kernel function significantly influences the overall performance of the canny edge detector and hence it exhibits that larger the size is, the minimal the detector's sensitivity would be due to noise presence. Furthermore, the localization error for edge detection might increase as per increase in the size of Gaussian filter kernel size. In this paper the kernel size has been considered as 10*10.

4. Estimation of Intensity Gradient

Th edge in an image might point in varied directions; therefore, canny algorithm employs multiple filters so as to perform the detection in horizontal, vertical and diagonal edges. The operators for edge detection such as Sobel, prewitt and Roberts can provide the first derivative value in horizontal direction and then in vertical direction. Thus the edge gradient can be found as

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

$$\Theta = atan2(G_y, G_x)$$

Where G_x is the horizontal direction and G_y is the vertical direction derivative.

Employing the above expression the edge gradient as well as the gradient direction could be found.

5. Non-Maximum Suppression

In fact it is an edge thinning scheme which is implemented for performing thinning of the detected edges. Once the gradient has been estimated the extracted edges from the gradient value are still found to be non-precise and blurred. Taking into consideration of the predominant criteria of canny edge detection, there must only be one precise edge response or results. Therefore, the implementation of non-maximum suppression performs the suppression of all the gradients values to 0 except the local maximal that represents the location of the edge having sharpest change in intensity. In this paper, the developed algorithm perform categorization of the continuous gradient directions into certain small set of discrete directions, which is then followed by the filter of 10*10 size over the outcome of the previous stage. In the developed algorithm at each pixel the algorithm performs the suppression of the edge strength of the centerpixel, in case the magnitude is found to be lower than the magnitude of its neighbouring pixels in certain gradient direction.

6. Double Threshold Based Optimization

Once the suppression has been performed, the edge pixels are found to be precise enough to represent the real edge. Then while, there exist some edge pixels caused due to noise factor and the variation in color intensity. Here in this paper work, in order to eliminate these issues, the edge pixels with weak gradients have been removed and only the gradients with higher value are considered for edge formation. In order to perform an efficient approach of edge detection in the initial phase of shape detection problem, in this algorithm two threshold have been defined, one for high threshold while another for low threshold values. In case the gradient of edge pixel is higher than the high threshold then those pixels are marked as strong edge pixels and vice versa. The pixels with the lower value as compared to the lower threshold are suppressed so as to give more accurate results.

The overall approach of the implementation of adaptive filter is given as follows:

- Estimate the gradient value

$$G_x\ (x,y)\ and G_y\ (x,y)$$

- Estimate weight value

$$d(x,y) = \sqrt{G_x(x,y)^2 and G_y(x,y)^2}$$

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

- Define the adaptive filter

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

where

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

In order to estimate the dual threshold value,all the pixel values are put in two sets $s_0$and s_1,which are distinguished by certain threshold factor T. Now, defining the associated pixel number of intensity level i is represented by a variablen_i. In such a way the probability of dual threshold is obtained by:

$$pi = \frac{n_i}{n}$$

Where $n$represents the number of the pixel points, the average of the gray level distribution probability can be obtained by the following expression:

$$\mu_T = \sum_{i=0}^{L-1}\frac{ip_i}{w_0}$$

$$w_0 = \sum_{i=0}^{L-1}\frac{p_i}{w_0}$$

$$u_1 = \sum_{i=T+1}^{L-1}\frac{ip_i}{w_1}$$

$$w_1 = 1 - w_0$$

The high threshold T is estimated as the parameter which can perform maximization of σ_b^2 and thus in this approach for individual image, its respective dual threshold value can be estimated to remove out those pixels which are not included in the real image edges.

7. Canny Edge Algorithm Based Ellipse Detection Shape Detection

In this paper work, in order to perform shape detection and specially the ellipse detection, the image sample under consideration has been convolved using a 2D first derivative operator for estimating the direction as well as the gradient magnitude of each pixel. Here it must be noted that the maxima as well as the minima of the first derivative gradient are found to be the same due to the zero-crossings of the second directional derivative. Here, only the maxima crossings have been taken into consideration due to its significance to represent the areas of the sharpest intensity variations in the image under consideration [1]. In this approach the zero-crossings are those pixels which do depicts the group of all the possible edges and the other pixels are suppressed. Ultimately, a dual-threshold based approach or hysteresis has been performed along the residual pixels so as to estimate the final group of edges [2].

In case, a single threshold, T1 is employed and certain edge possesses an average strength T1, then because of the noise factors, there would be certain occasions when the edge decreases below certain defined threshold. In order to eliminate the situation where the edge look like dashed lines, in this paper a dual threshold based hysteresis has been employed that makes the detection more perfect and accurate. Here in this paper, any pixel which is having a value greater than higher threshold T1 has been considered as an edge pixel and it has been taken into consideration for edge presentation and marking. Here any pixels that are connected to the marked edge pixel (with pixel value more than T2) are also considered as edge pixels.

In this section, the ellipse expression and its detection has not been discussed as th theoretical analysis and its discussion has already been done in the previous chapter (Ellipse detection, Chapter-3). In this paper, the freeman chain algorithm has been employed for shape (Ellipse, Line and Circle detection).

8. FREEMAN CHAIN CODE FOR ELLIPSE DETECTION

In fact, the chain code algorithm is the list of codes that ranges from 0 to 7 in the clockwise direction and these specific codes presents the direction of the next pixel associated with 3*3 windows. In this algorithm the coordinates of the adjacent pixel has been estimated on the basis of the process of addition and subtraction of certain columns and row by 1 that depends on the value of chain code under consideration. In this paper, the Freeman chain code has been employed. The following table represents the location of the next pixels (table-2) of pixels in Table 1.

	Column-1	**Column**	**Column+1**
Row-1	5	6	7
Row	4	Current pixel	8
Row+1	3	2	1

Table2. *Pixel position*

Current Pixel at coordinate (5,5)		
Code	**Next Row**	**Next Column**
0	5	5
1	6	6
2	6	5
3	6	4
4	5	4
5	4	4
6	4	5
7	4	6

Consider the case when the current pixel is located at the coordinate of (5, 5), then the respective coordinate of the next pixel is given in Table-2. Here the only limitation is that the implementation of Freeman chain approach would have to perform scanning of the entire neighbouring pixel while performing shape detection.

In the algorithm, the chain code has been estimated from the boundary or the edges obtained using canny edge detection by performing the sub-sampling of the edges found and then assigning a specific number such as (0-3) in case of 4connectivity and (0-7) if there is 8 connectivity when moving from one edge to another. It depicts that freeman chain code is nothing else but the trajectory of the traversal from one point to another, where the individual direction or the trajectory is specified by certain number. In this paper, 8-connectivity has been employed and thus the overall process of shape detection using freeman chain code is given as follows:

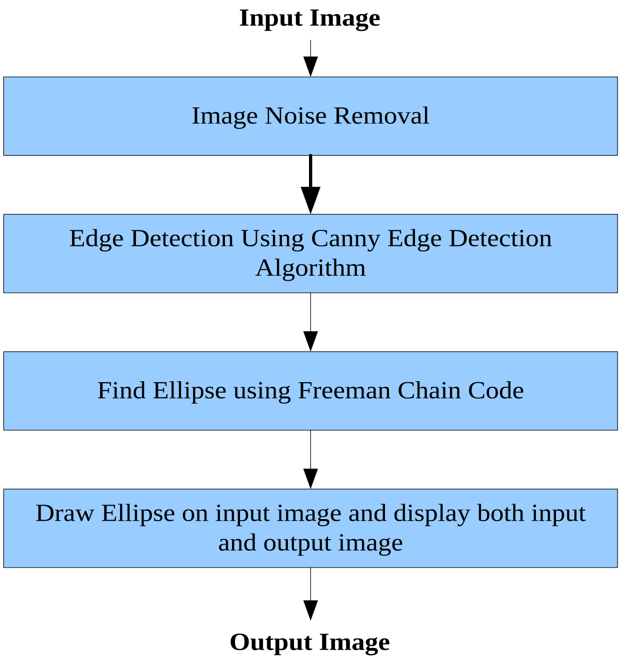

Fig1. *Modified Canny Edge based Ellipse Detection*

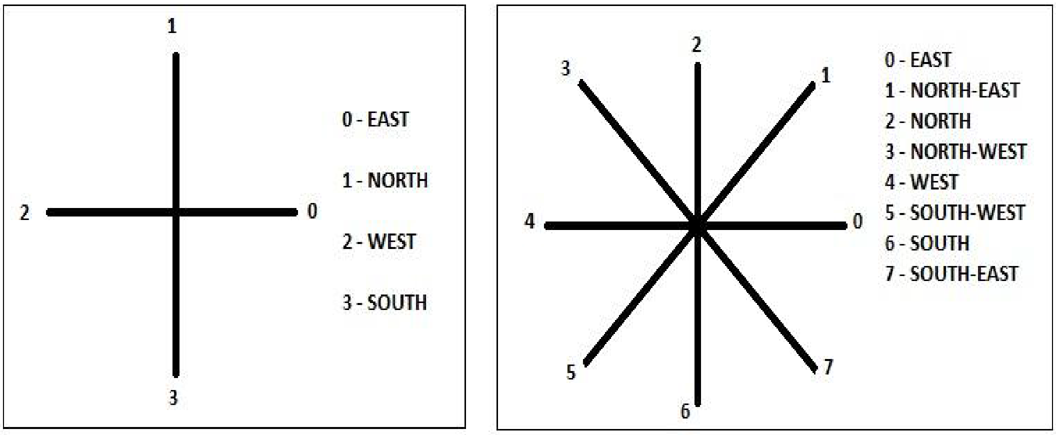

Fig2. *Freeman Chain code*

9. Canny Edge Based Circle Detection

In this paper, the canny edge detection scheme has been employed for circle detection because of its robust functions for edge detection and optimal accuracy. Even, this scheme exhibits better results as compared to other operators such as Sobel, Prewitt and Robert cross operators. Similar to the ellipse detection scheme, here in this step once the canny edge detection has been done, the Freeman chain code algorithm has been employed for the detection of shapes (here circle). Here the images of varied types such as synthetic as well as natural are considered for shape detection. In general there are two predominant principles for detecting the edges that form boundary of certain object. These are:

- Based on edge strength, and
- Based on pixel direction [3].

In this algorithm the deployed chain code for contour tracing is given as follows:

Table3. *Chain code*

	Column-1	Column	Column+1
Row-1	5	**6**	7
Row	4	**Current pixel**	8
Row+1	3	2	1

Table4. *Pixel position*

Current Pixel at coordinate (x,y)		
Code	**Next Row**	**Next Column**
0	x	y
1	x + 1	Y+1
2	x + 1	y
3	x + 1	y-1
4	X	y-1
5	x – 1	y-1
6	x – 1	y
7	x - 1	Y+1

The following figure 3 represents the flow diagram of chain algorithm and modified canny edge detector based shape (circle detection) [4].

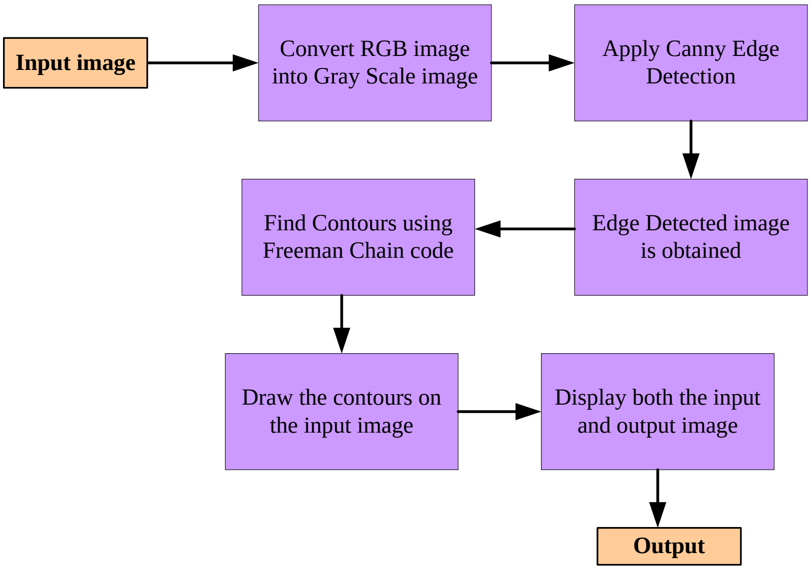

Fig3. *Proposed approach of circle detection*

Similar to the other approaches of shape detection, in this paper the modified canny edge detection has been employed for line detection using chain code approach as discussed in the above section. In this paper, similar to the previous approaches for shape detection, the lines have been detected using the canny edge detection algorithm enriched with dual threshold based hysteresis and adaptive Gaussian filer which has been followed by the implementation of chain code scheme for shape (here, line) detection in the image of interest.

Simulation Results

The following figure represents the performance analysis of shape detection using canny edge approach enriched with Freeman chain code scheme.

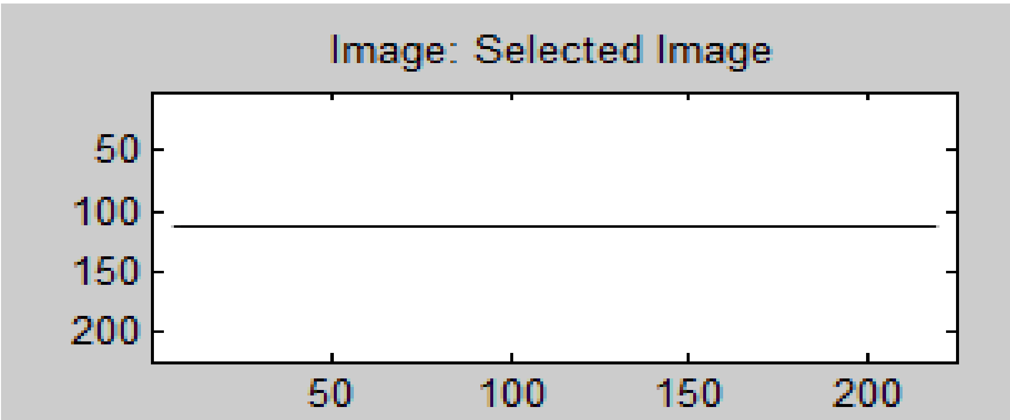

Fig4. *Original image of Line*

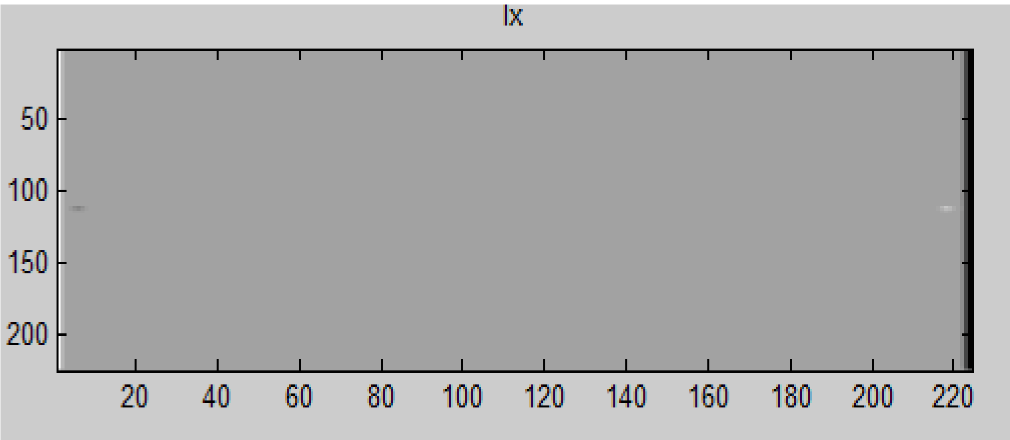

Fig5. *Horizontal component*

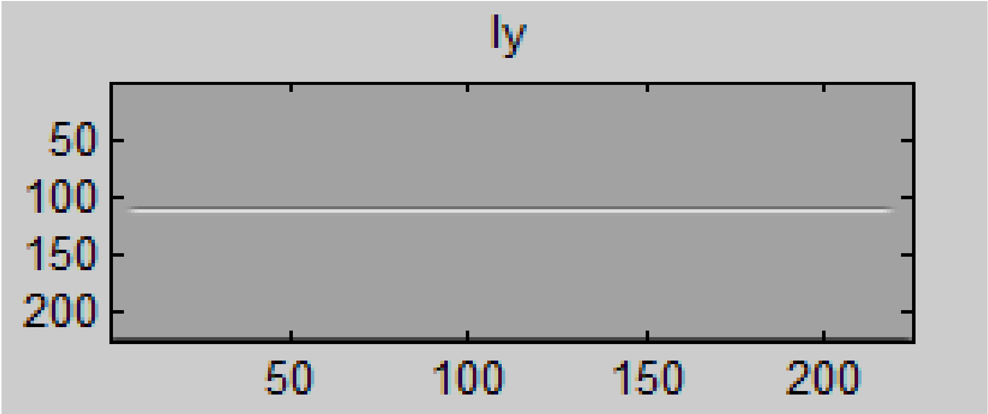

Fig6. *Vertical component scanning*

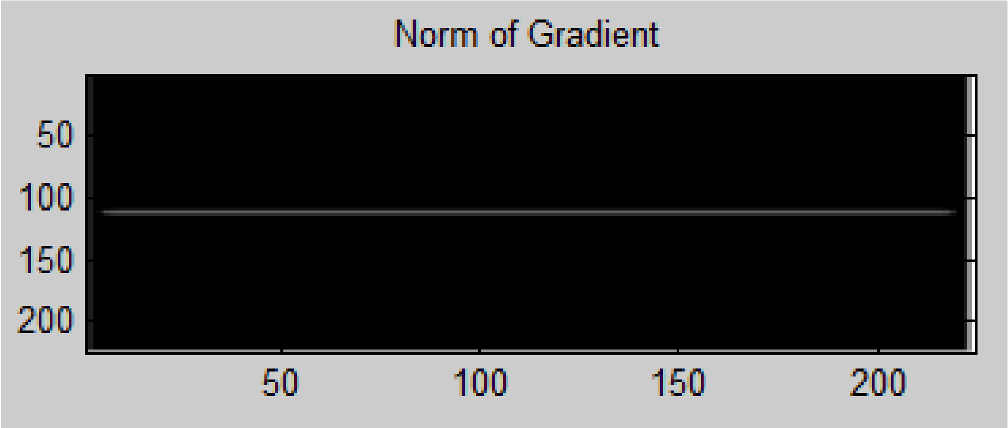

Fig7. *Obtained Norm of gradient*

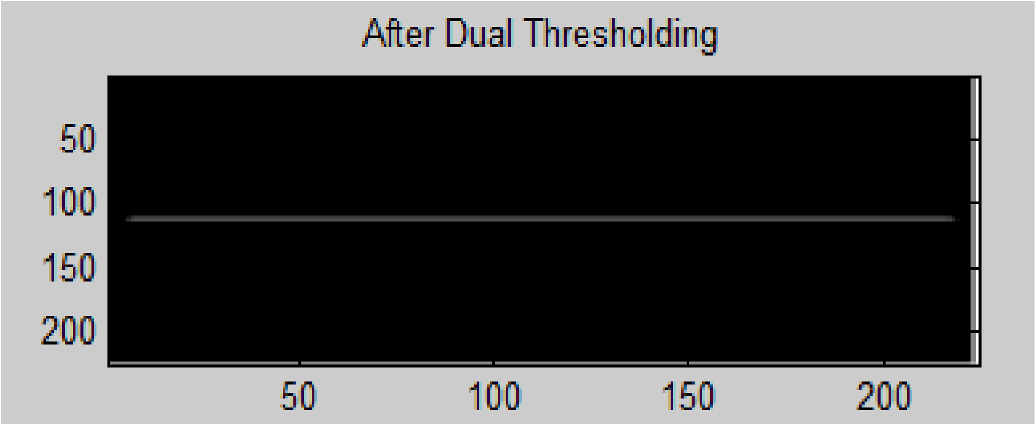

Fig8. *Detected Image after dual thresholding*

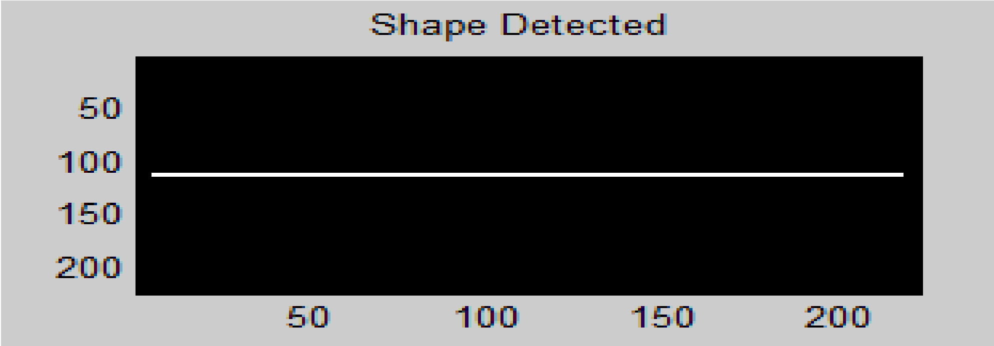

Fig9. *Detected Line*

The results obtained for circle detection using Modified Canny Edge algorithm is

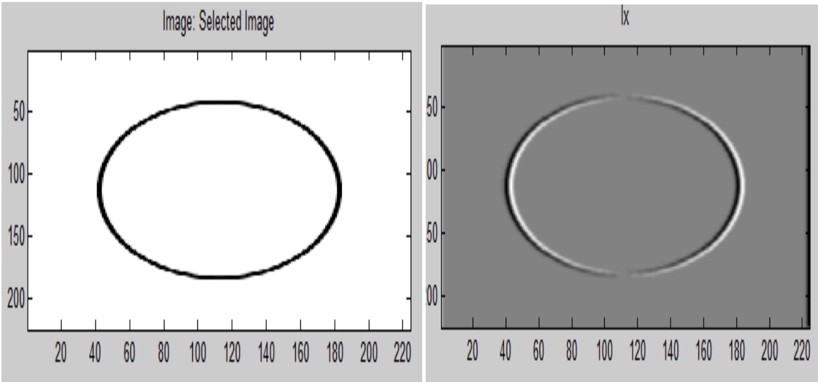

Fig10. *Image for test, Figure Horizontal scanned Image component*

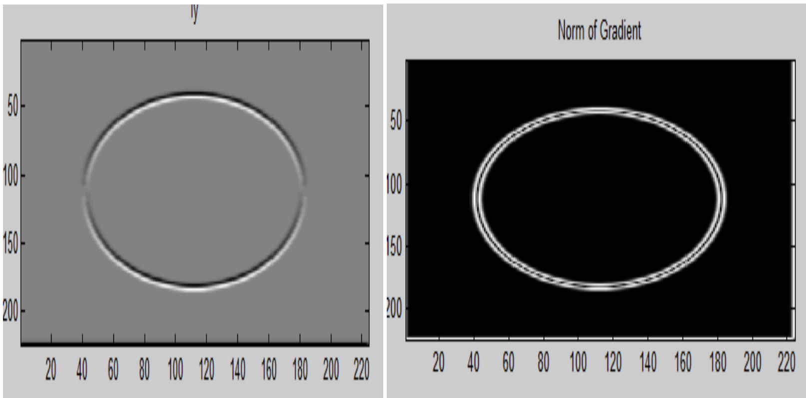

Fig11. *Vertical scanned Image component, Figure Norm of Gradient for image of interest*

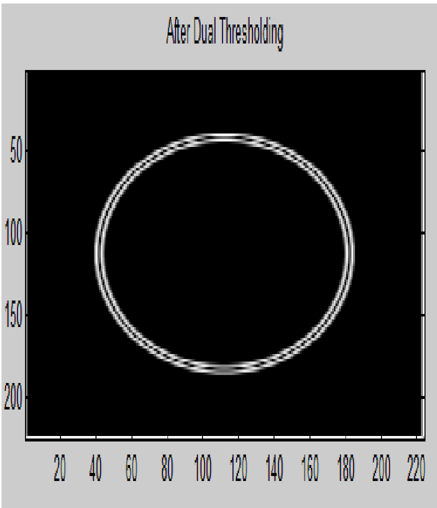

Fig12. *Detected Circle*

The overall results accomplished states that the presented algorithm is efficient for shape detection.

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