Comparison of Optimal Edge Detection Algorithms for Liquid Level Inspection in Bottles

Conference Paper · January 2010

DOI: 10.1109/ICETET.2009.55 · Source: IEEE Xplore

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Comparison of optimal edge detection algorithms for liquid level inspection in bottles

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***Abstract*: In this paper few optimal edge detection techniques, used to inspect the over and under fill liquid level of bottle in machine vision system are compared. The text represents the steps and approaches for the inspection of over and under filled level in the bottle which would not only be helpful for quality inspection but in précised time too using different edge detection techniques. The results of Different optimal edge detection algorithm such as Marr- Hilderth LoG algorithm , Canny algorithm and Shen Castan algorithm were found to be much better than the traditional template based methods like Sobel and Kirsch operators.**

Keywords: Quality control, Machine Vision, Optimal Edge detection, ISEF (Shen Castan algorithm), Canny Edge Detection, LoG.

I. Introduction

MACHINE or electronic perception is one of the important advanced technological field where significant developments have been made. Machine perception attempts to mimic sensory perception of human beings. Scientists have successfully endowed computers with vision by sophisticated digital cameras and machines. Intense research is in progress all over the world on applications of machine vision based systems. Machine vision system plays a vital role in manufacturing application, quality inspection and process monitoring as well. Traditionally, quality inspection is performed by trained human inspectors. In addition to being costly, this method is highly variable and decisions are not always consistent between inspectors or from day to day. This is, however, changing with the advent of electronic imaging systems and with the rapid decline in cost of computers, peripherals and other digital devices.

Taking one application of inspection of bottle filling, the method is very fast, quiet repetitive and subjective in nature. In this type of environment, machine vision systems are ideally suited for routine inspection and quality assurance tasks. Backed by powerful state-of-the-art electronic technologies, machine vision provides a mechanism in which the human thinking process is simulated artificially. In machine vision based systems many edge detection techniques proposed by many researchers are prevailing. Each technique works nicely for the particular application only. There is not a general consensus about one or couple of methods to be used for edge detection in machine vision community. Significant work in bottle defect detection and in bottle filling level inspection is done.

In the area of bottle defect detection enough literature can be found out, while in case of bottle filling level inspection cited literature is not available due to its inherently simple task of edge detection and distance measurements. But the latest developments in the field of optimal edge detection algorithms are still untouched particularly in the application of bottle filling inspection. In [1] Y. Wang et al. proposed an algorithm for bottle finishing using Hough transform methods which would detect the defected bottle from the bulk and separate it out. In [2] Y. Wang et al. proposed watershed algorithm for bottle inspection by detecting out the possible defective regions in the upper portion of the bottle called the neck of the bottle and extracting these features from the image. Further for the purpose of classification the optimal hyper plane concept based on SVM method was used. In [3] Hui-MinMa et al. proposed an automatic inspection system based on eight CCD cameras which would give a decision about good or bad bottle based on top lead of the bottle. In [4] F.Daun et al. proposed a new algorithm stating that Hough transform and edge detection is a slow process so by analyzing the histogram of the edges of the bottle. Based on those edges an analysis was done on the shape and size of the bottle.

Motivated by the optimal edge detection techniques like LoG, Canny edge detection and ISEF edge detection, in this paper we apply LoG, Canny & ISEF edge detection methods to inspect the filling level of the bottle. In section II we discuss the problem of filling water bottle. Section III is regarding optimal edge detection techniques for filling level inspection using machine vision. In section IV we propose an algorithm for liquid level inspection. In section V results are given. Section VI concludes the paper.

II. Problem Definition

Filling bottle using machine with accuracy is subject to

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978-0-7695-3884-6/09 $26.00 © 2009 IEEE

error from a wide variety of potential problems from flow rates to glass bottle variations. To ensure consistent fill levels 100% quality inspection is required. Inspection systems must also be capable of keeping up high speed filling / bottling machinery. Fig-1 shows a schematic of bottle filling system. Failure to properly fill bottles to the correct volumes as stated on packaging results in loss of customer loyalty, consumer fraud allegations and recalls. For instance if the milk bottles are not properly filled which are prescribed for the babies then the proper nutrition in the required amount would not reach to the baby's body which results in loss of customer loyalty as well as fraud allegations. Overfilling results in giving away products and profits. The images of overfilled and under filled bottles are shown in Fig-2.

The inspection method chosen is fast enough to keep up with high speed filling machines and provide accurate and repeatable results. An approach to the above problem is made by extracting the edges from the image captured by a 3.2 mega pixel camera and then applying a distance based novel technique, to make a decision on the above said problem of over and under filling bottle inspection.

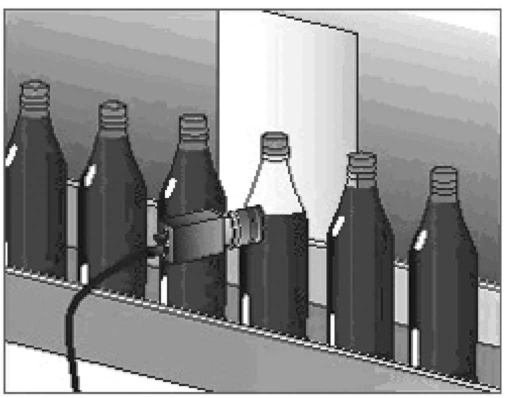

Fig 1: Outline of Bottle level filling system
{Courtesy: OMRON Tech. for focused Automation [4]}

III. OPTIMAL EDGE DETECTION TECHNIQUES

Edge detection is one of the most commonly used operations in image analysis. An edge is defined by a discontinuity in gray level values and is the boundary between an object and the background. Many edge detectors are available based on templates. The first of these is the Sobel edge detector having the following values. One way to view these templates is as an approximation to the gradient at the pixel corresponding to the center of the template.

$$Sy= \begin{matrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{matrix} \qquad Sx= \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix}$$

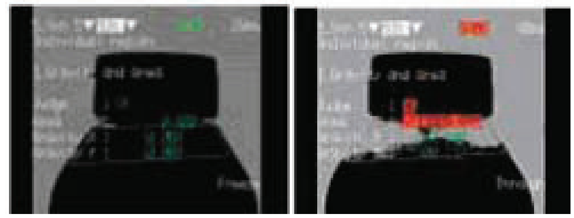

Fig 2: Over and Under filled bottles
{Courtesy: OMRON Tech. for focused Automation [4]}

Another 3*3 template defined by Kirsch is given as,

$$k0= \begin{matrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{matrix} \quad k1= \begin{matrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{matrix} \quad k2= \begin{matrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{matrix} \quad k3= \begin{matrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{matrix}$$

$$k4= \begin{matrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{matrix} \quad k5= \begin{matrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{matrix} \quad k6= \begin{matrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{matrix} \quad k7= \begin{matrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{matrix}$$

These masks are an effort to model the kind of grey level change seen near an edge having various orientations, rather than an approximation to the gradient. There is one mask for each of eight compass directions. Referring to Any template based edge detector, it is having specific application. The main disadvantage of these edge detectors is their dependence on the size of the object, they are having high Sensitivity to noise, and Inaccurate too.

Marr's theory concluded from neurophysiological experiments that object boundaries are the most important cues that link an intensity image with its interpretation. Marr studied the literature and explored the fact that a step edge corresponds to an abrupt change in the image function. The first derivative of the image function should have an extremum at the position corresponding to the edge in the image, and so the second derivative should be zero at same position, however it is much easier and more precise to find zero crossing position than an extremum.

A. LoG ALGORITHM [9]

LoG is outlined in Table-I for which Locality is not especially good and the edges are not always thin. Still it is much better than the previous one in case of low signal to noise ratio.

TABLE I
LOG ALGORITHM

No.	STEPS
1	Convolve image I with a 2D Gaussian function.
2	Compute Laplacian of convolved image, call it L.
3	Edge pixels are those for which there is a zero crossing in L.

Malfunctioning at corners, curves and where the gray level intensity function varies, not finding the orientation of edge because of using the Laplacian filter. Two advanced and optimized edge detectors are Canny Edge Detectors and (Shen and Castan's) Infinite Symmetric Exponential Filter (ISEF). Both are classified as Mathematical Edge Detectors.

B. CANNY ALGORITHM [7]

Canny specified three issues that an edge detector must address. These are: 1. Error rate: the edge detector should respond only to edges, and should find all of them; no edges should be missed. 2. Localization: the distance between the edge pixels as found by the edge detector and the actual edge should be as small as possible. 3. Response: the edge detector should not identify multiple edge pixels where only a single edge exists.

Canny algorithm (Table II) convolves the image with the derivative of a Gaussian, the Canny implementation uses a wrap-around scheme when performing the convolution, and the areas near the boundary of the image are occupied with black pixels, although sometimes with what appears to be noise. Shen and Castan's filter gives better signal to noise ratios than Canny's filter and provides better localization.

This could be because the implementation of Canny's algorithm approximates his optimal filter by the derivative of a Gaussian, whereas Shen and Castan use the optimal filter directly, or could be due to a difference in the way the different optimality criteria are reflected in reality.

C. ISEF ALGORITHM [5]

The edge can be detected by any of template based edge detector but Shen-Castan Infinite symmetric exponential filter based edge detector is an optimal edge detector like

TABLE II
CANNY ALGORITHM

No.	STEPS
1	Read the image I.
2	Convolve a 1D Gaussian mask with I.
3	Create a 1D mask for the first derivative of the Gaussian in the x and y directions.
4	Convolve I with G along the rows to obtain Ix, and down the columns to obtain Iy.
5	Convolve Ix with Gx to have Ix', and Iy with Gy to have Iy'.
6	Find the magnitude of the result at each pixel *(x, y).* $M(x,y)=\sqrt{I'_x(x,y)^2+I'_y(x,y)^2}$

Canny edge detector which gives optimal filtered image. First the whole image will be filtered by the recursive ISEF filter in X direction and in Y direction, which can be implement by using equations as written below.

Recursion in x direction:

$$y_1[i,j]=\frac{(1-b)}{(1+b)}\;I[i,j]+b\,y_1[i,j-1], \qquad (1)$$

$$j=1...N,\, i=1..M$$

$$y_2[i,j]=b\frac{(1-b)}{(1+b)}\;I[i,j]+b\,y_1[i,j+1] \qquad (2)$$

$$j=N...1, i=1..M$$

$$r[i,j]=y_1[i,j]+y_2[i,j+1] \qquad (3)$$

Recursion in y direction:

$$y_1[i,j]=\frac{(1-b)}{(1+b)}\;I[i,j]+b\,y_1[i-1,j], \qquad (4)$$

$$i=1...M,\, j=1..N$$

$$y_2[i,j]=b\frac{(1-b)}{(1+b)}\;I[i,j]+b\,y_1[i+1,j], \qquad (5)$$

$$i=M...1,\, j=1..N$$

$$y[i,j]=y_1[i,j]+y_2[i+1,j] \qquad (6)$$

b=Thinning Factor ($0<b<1$)

Then the Laplacian image can be approximated by subtracting the filtered image from the original image. At the location of an edge pixel there will be zero crossing in the second derivative of the filtered image. The first derivative of the image function should have an extreme at the position corresponding to the edge in image and so the second derivative should be zero at the same position. And for thinning purpose apply non maxima suppression as it is used in canny for false zero crossing.

TABLE III
ISEF ALGORITHM [5]

No	Steps
1	Apply ISEF Filter in X direction
2	Apply ISEF Filter in Y direction
3	Apply Binary Laplacian Technique
4	Apply Non Maxima Suppression
5	Find the Gradient
6	Apply Hysteresis Thresholding
7	Thinning

The gradient at the edge pixel is either a maximum or a minimum. If the second derivative changes sign from positive to negative this is called positive zero crossing and if it changes from negative to positive it is called negative zero crossing .We will allow positive zero crossing to have positive gradient and negative zero crossing to have negative gradient, all other zero crossing we assumed to be false and are not considered to an edge. Now gradient applied image has been thinned, and ready for the thresholding.

The simple thresholding can have only one cutoff but Shen-Castan suggests to use Hysteresis thresholding. Spurious response to the single edge caused by noise usually creates a streaking problem that is very common in edge detection. The output of an edge detector is usually thresholded, to decide which edges are significant and streaking means the breaking up of the edge contour caused by the operator fluctuating above and below the threshold.

Streaking can be eliminated by thresholding with Hysteresis. Individual weak responses usually correspond to noise, but if these points are connected to any of the pixels with strong responses, they are more likely to be actual edge in the image. Such connected pixels are treated as edge pixels if there response is above a low threshold. Finally thinning is applied to make edge of single pixel. The ISEF algorithm is given in Table III.

IV. PROPOSED ALGORITHM

Image of a filled bottle is captured using a CCD camera as shown in Fig-3. The image is cropped to make it a normalized image with respect to height of the conveyor belt. For the comparative study, different Edge detection techniques like Canny, LoG and ISEF Edge detection techniques can be applied. The required steps for each edge detection algorithms are given in Tables I, II and III respectively. The proposed algorithm is outlined in Table IV. We propose a simple and novel algorithm to decide the over/under filling level of bottle based on distances from the center of the region of interest (ROI). The algorithm is presented in Table V.

TABLE IV
PROPOSED ALGORITHM

No.	Steps
1.	Capture the image.
2.	Apply an optimal Edge detection Algorithm
3.	Find a region of interest (ROI)
4.	Apply the proposed technique of table 5 to conclude about the over/under filling of bottle.

TABLE V
STEPS FOR FINDING AVERAGE DISTANCE

No.	Steps
1	Decide a horizontal region of interest (Figure 4)
2	Bottom line of the cap neck end is taken as a reference. (Figure 5)
	For each and every pixel having value 1 in box 1 (Figure 5) find a pixel having value 1 in box 2.
4	Find the vertical distance between these two pixels. Do it for all the pixels having value 1, in both boxes 1 and 2. (Figure 6)
6	Take the average of all distance lines: *avgd*.
	If *avgd* > the datum distance (Figure 7, red line), the bottle is over filled. If *avgd* < the datum distance the bottle is under filled.

Fig-3: Original Image

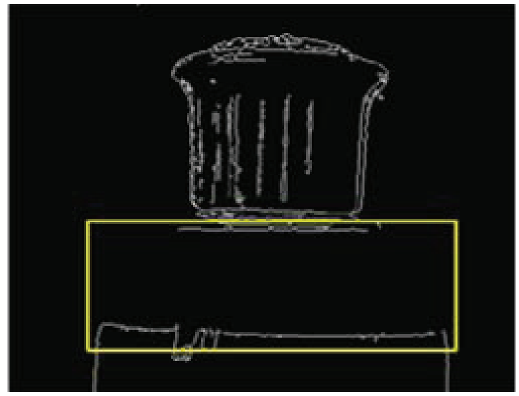

Fig-4: Image with Region of Interest

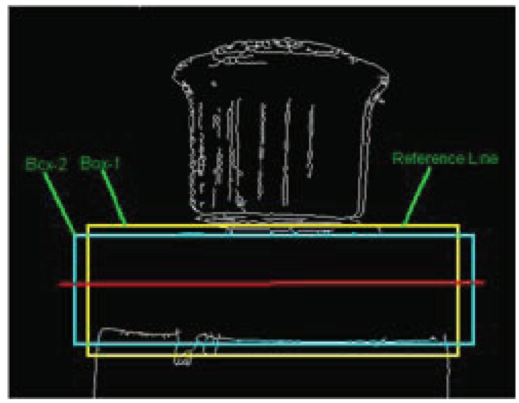

Fig-5: Image with Regions in BOX 1 & BOX 2

V. RESULTS

After applying the proposed algorithm we get the distances as given in appendix for which the avg. distances are available as shown in Table-VI. The variation of distances which we get after applying the proposed algorithm for each edge detection technique is shown in Fig-11, 12 & 13. From Fig-11, 12 & 13 we can conclude that the distance variation, found using LoG & Canny is not so regulated as compared to ISEF.

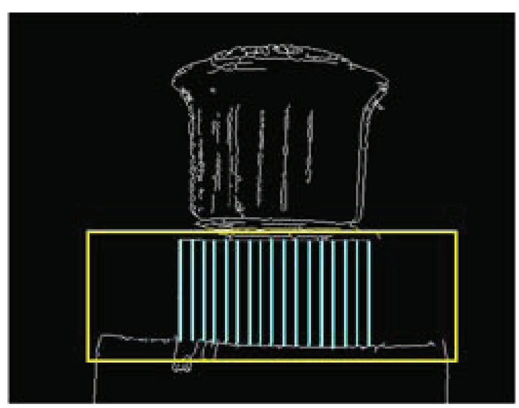

Fig-6: Image with distance lines

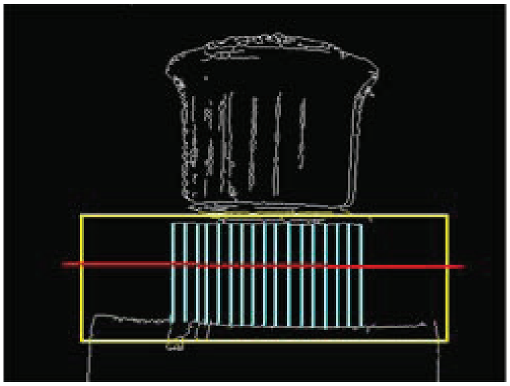

Fig-7: Image with datum line differentiating the Level

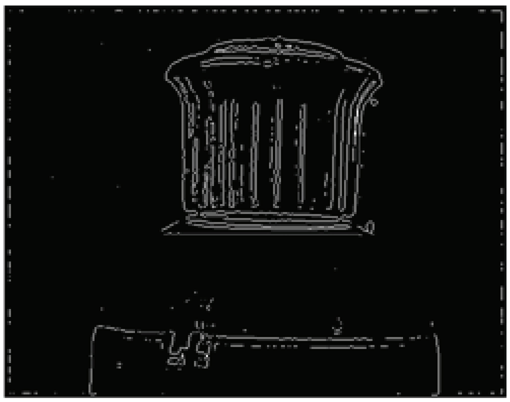

Fig-8: Image after the edge detection (LoG)

TABLE-VI
DISTANCE FOUND USING AVERAGE

Avg. Distance	LoG	Canny	ISEF
(in No. of pixel)	**101**	**112**	**107**
(in mm)	**35.68**	**39.5**	**37.63**

VI. CONCLUSION

In this paper we have compared performance of different edge detection techniques for a simple application of water bottle level filling inspection using machine vision system.

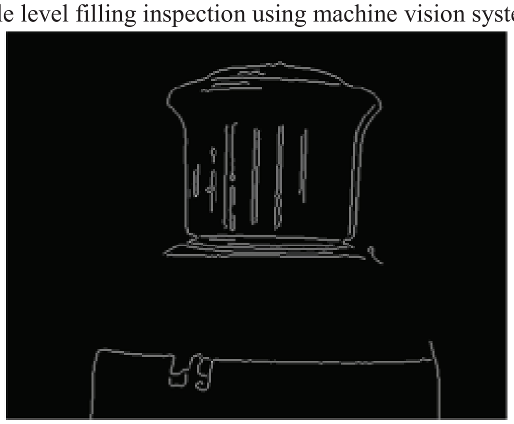

Fig- 9: Image after the edge detection (Canny)

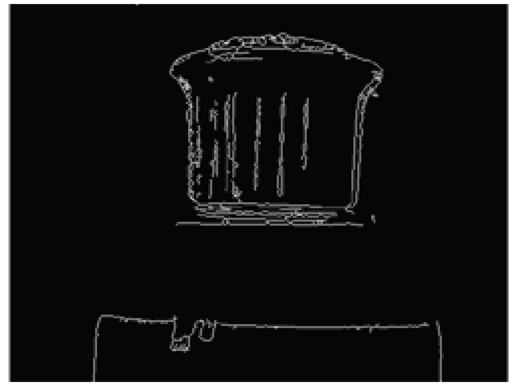

Fig 10: Image after the edge detection (ISEF)
(b=0.6,HT=100 ,LT=50, thinning-8)

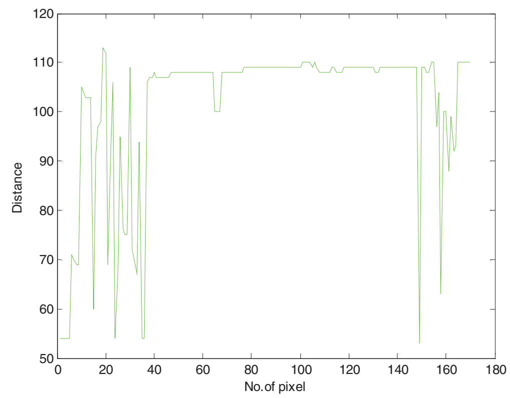

Fig-11: Linear distance plot for LoG

The optimal edge detection techniques are applied and the results obtained are so good and can give better decision about the over and under filled bottle.

REFERENCES

[1] Y.Wang "A Real Time Machine Vision System For Bottle Finish Inspection"2004 8th International Conference On Control Automation Robotics And Vision, China.(2004).

[2] Y.Wang "Glass Bottle Inspector Based On Machine Vision"2008 International Journal Of Intelligent Systems And Technologies(2008)

[3] Hui-MinMa" A Glass Bottle Defect Detection System Without Touching" Proceeding Of The First International Conference On Machine Learning And Cybernetics,Beijing,November (2002)

[4] OMRON Tech. focused for automation solutions.

[5] K J Pithadiya "Performance evaluation of ISEF and Canny edge detector in Acrylic fiber quality control production" , Proceedings of National Conference on Innovations in Mechatronics Engineering ,GCET, V V Nagar, India, pp89-92 (2009)

[6] Paulo Heleno , "A Machine Vision Quality Control System for Industrial Acrylic Fibre Production", EURASIP Journal on Applied Signal Processing 2002:7, 728–735 (2002)

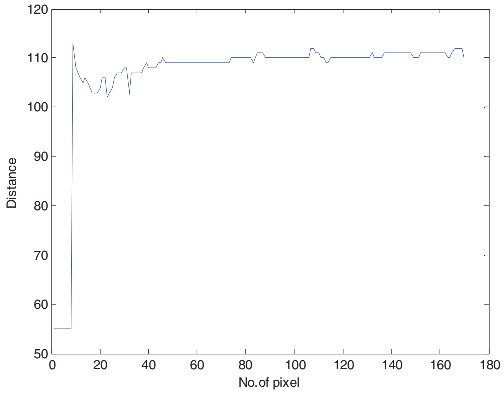

Fig-12: Linear distance plot for ISEF

[7] Canny, J., "A Computational Approach to Edge Detector", IEEE Transactions on PAMI, pp679-698, (1986).

[8] Alberto Martin, "Image Processing Techniques for machine vision", Miami, Florida, (2000).

[9] Mohsen Sharifi, " A Classified and Comparative Study of Edge Detection Algorithms" Proceedings of the International Conference on Information Technology: Coding and Computing (2002) IEEE .

[10] Jozˇe Derganc, "A Machine vision system for measuring the eccentricity of bearings",Computers in Industry ,Vol 50 (2003) 103–111.

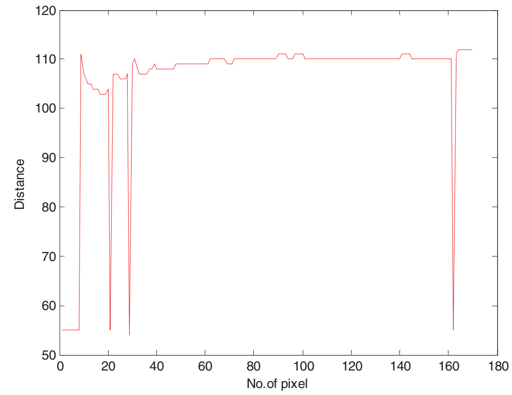

Fig-13: Linear distance plot for Canny

APPENDIX

Canny	LOG	ISEF	Canny	LOG	ISEF	Canny	LOG	ISEF	Canny	LOG	ISEF	Canny	LOG	ISEF	Canny	LOG	ISEF
55	54	55	109	109	108	109	108	109	110	109	110	110	108	110	110	109	111
55	54	55	110	72	108	109	108	109	110	109	110	110	109	110	110	109	111
55	54	55	108	69	103	109	108	109	111	109	110	110	109	110	110	109	111
55	54	55	107	67	107	110	108	109	111	109	110	110	109	110	110	53	110
55	54	55	107	94	107	110	108	109	111	109	110	110	109	110	110	109	110
55	71	55	107	54	107	110	108	109	111	109	110	110	109	110	110	109	110
55	70	55	107	54	107	110	100	109	110	109	110	110	109	110	110	108	111
55	69	55	108	106	107	110	100	109	110	109	110	110	109	110	110	108	111
111	69	113	108	107	108	110	100	109	110	109	110	110	109	110	110	110	111
107	105	108	109	107	109	110	108	109	111	109	110	110	109	110	110	110	111
106	104	107	108	108	108	109	108	109	111	109	110	110	109	110	110	97	111
105	103	106	108	107	108	109	108	109	111	109	110	110	109	110	110	104	111
105	103	105	108	107	108	109	108	109	111	109	110	110	109	110	110	63	111
104	103	106	108	107	108	110	108	109	110	110	110	110	109	110	110	100	111
104	60	105	108	107	109	110	108	109	110	110	110	110	108	110	110	100	111
104	91	104	108	107	109	110	108	110	110	110	110	110	108	111	110	88	111
103	97	103	108	107	110	110	108	110	110	110	110	110	109	110	55	99	111
103	98	103	108	108	109	110	108	110	110	109	110	110	109	110	111	92	110
103	113	103	109	108	109	110	109	110	110	110	110	110	109	110	112	93	110
104	112	104	109	108	109	110	109	110	110	109	112	110	109	110	112	110	111
55	69	106	109	108	109	110	109	110	110	108	112	110	109	111	112	110	112
107	92	106	109	108	109	110	109	110	110	108	111	110	109	111	112	110	112
107	106	102	109	108	109	110	109	110	110	108	111	110	109	111	112	110	112
107	54	103	109	108	109	110	109	110	110	108	110	110	109	111	112	110	112
106	68	104	109	108	109	110	109	109	110	108	110	111	109	111	112	110	110
106	95	106	109	108	109	110	109	110	110	109	109	111	109	111			
106	76	107	109	108	109	110	109	111	110	109	109	111	109	111			
107	75	107	109	108	109	110	109	111	110	108	110	111	109	111			
54	75	107	109	108	109	110	109	111	110	108	110	110	109	111			