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Improved Canny Edge Detection Technique Using S-Membership Function

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Abstract: ***Traditional Canny edge detection algorithm is sensitive to noise, hence it may lose the weak edge information after noise removal and show poor adaptability of fixed parameters like threshold values. In view of these problems, this paper reports on the modification of canny edge detection algorithm using s-membership function. Adaptability of threshold values are achieved through S-membership function and is given as input to default Canny algorithm. The grayscale images have been analyzed for default Canny and modified Canny algorithm. To understand the performance of these algorithms it is essential to evaluate various statistical metrics. The proposed work states that the detailed statistical results and the images obtained reveal the superior performance of the modified Canny algorithm over the default Canny edge detection algorithm. Further the images obtained from modified Canny algorithm shows the marked edges with efficient image edge extraction and provide accurate information for image measurement.***

Index Terms: Canny edge detection, grayscale image, S-membership function, Improved Canny algorithm, and threshold.

I. INTRODUCTION

Digital image processing generally uses computer algorithms for digital image operations like feature extraction, pattern recognition, segmentation, image morphology etc. Edge is treated as an important feature of an image to estimate the property and structure of objects in a scene. Edges typically recognized at the border line between two dissimilar regions in an image. Local change in the intensity of the image may treat as an important parameter in detecting the image edge. It could be associated with the sharp discontinuity may be in the image intensity or of its first derivative. Edge detection is frequently be used in the image processing as the first step in recovering useful information from images. The significance of edge detection in an image processing is to minimize the quantity of data to be processed.

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Edges characterize boundaries with a boundary pixel which connects two different regions with changing parameters such as intensity values in an image. Developments of varieties of edge detection techniques are paying attention in the field of image processing. Detection of edges is usually an image segmentation technique, which partitions the image in the spatial domain into meaningful regions. The detection operation initiates by examining the discontinuity locally at the pixel location of an image. Edge detection technique discriminates the two regions based on the features extracted from the boundary pixel intensities. The edge detection process shows practical applications in face recognition and fingerprint recognition, medical imaging, locate object in satellite images, automatic traffic controlling systems, computer assisted surgery diagnosis, study of anatomical arrangement etc. It is evident from the literature that there exists extremely vast number of operators for edge detection. Each operator is sensitive to certain types of edges and involves lot of variables such as organization of edges, noise background and direction of the edge. The edge operators usually verify the direction in which it is most sensitive to edges. Based on the characteristics, the edge detector decides whether every examined pixel can be recognized as an edge or not.

Over the past decade, many edge detection techniques were developed so for to identify the true edges from the gray scale/color images. The edge detection techniques are basically classified into two groups based on a number of operators such as first order and second-order derivatives like Sobel, Prewitt, LoG and Canny based edge detection techniques. First order derivative (Gradient based) classical operators were globally established for detection of edges but they were highly responsive to noisy images. The limitations of Laplacian based Marr Hildrith operators is two folded like false edge detection with high probability and for curved edges error localization is very much pronounced. Majority of the researchers believed that the algorithm suggested by John F. Canny in 1986 is an ideal edge detection algorithm for the noisy images. In general, the main intention of the Canny's algorithm was the identification of the most suitable edge detection algorithm which gives less false edges and should also produce much distinctive sharp edges [1-5].

Edge detection is very much needed to determine the right edges to get the best results out of the matching process. It is very much essential to choose the right edge detectors that fit best to the specific applications. The algorithms for edge extraction which were developed in the past two decades did not give good results for functionality and performance.

All the proposed edge detecting operators are not fully suitable in the actual world. The selection of suitable edge detector is much important by considering precision, resolution and accuracy of detecting the true edges [6, 7]. According to Canny [5], three important properties of a best suitable edge detector should include

1. *Good detection* which should have much effectively selecting the real image edges at the same time strictly rejecting the selection of non-edge points.
2. *Good localization* may be regarded as the points marked as edges should be much closer to the center of true edges and
3. Should have only single response to an edge point.

Good detection is achieved by improving the signal-to-noise ratio (SNR). According to Canny algorithm, the measure for good localization is the inverse of the RMS distance of the marked edge from the midpoint of the original edge. To improve both localization criteria and good detection, Canny algorithm used to maximize the product of the standard deviation of the displacement of edge points and SNR value. This product significantly gets rid of multiple responses to a single edge point.

Many of the diverse applications accepted that the Canny edge detection algorithm provides better results when compared to other edge detectors because it assures better localization, high quality of edge detection, and single response [8].

II. DRAWBACK OF CONVENTIONAL CANNY ALGORITHM

Optimization theory is the basis for the evaluation of Canny operator. This edge detection technique involves different stages. First stage of the edge detection process is image smoothening process with Gaussian filter. The filtering process smoothes the high frequency content of the image that may contain the edge pixels leads to the loss of edge information. Second stage in Canny edge detection involves thresholding process. The low and high thresholds can be manually set but it requires prior empirical knowledge which possibly be obtained by doing many experiments. In practice, scenes and illumination change frequently so the high and low thresholds often changes. In many cases, the edge detector cannot obtain satisfying results due to the lack of the capability of self adaptation.

The traditional Canny edge detection algorithm is more widely accepted in practical engineering. However improvements are still needed for the traditional Canny algorithm. The first improvement is that the traditional Canny algorithm calculates image gradient from the first order difference of 2×2 neighboring area. But this process is severely sensitive to noise. Further its is easy to lose true edge information as the deviation of edge directions of 45° and 135° are not taken into account. On the other hand, double threshold is another problem in the traditional Canny algorithm which sets fixed value. The processing of images with rich edge information makes Canny algorithm inefficient which sometimes lose the essential characteristic features of the edge information.

III. IMPORTANCE OF MEMBERSHIP FUNCTIONS IN IMAGE PROCESSING

Generally, Membership function represents in the form of a curve where the membership value can be varied between 0 and 1. Further the function can also specify how effectively the membership value can be mapped to each point of the input space. The membership function quantifies the degree of an element to a fuzzy set. The fuzzy set can be fully defined by the membership function which can be in any form. But there are some widespread examples of functions that they become visible in real world applications.

The varieties of membership functions with different shapes are available like triangular, trapezoidal, piecewise-linear, Gaussian, bell-shaped, and so on. The choice of fuzzy-membership function is based on the specific application.

The shape of S-function significantly determines the degree of brightness or whiteness of pixels in grey scale images. The S-function was at first defined by Zadeh [9]. S-function is more simplistic and demands less computational complexity with our simplification of linguistic hedges based on image basic characteristics. But this method can be further improved and tested against other fuzzy membership functions available or a still new suitable membership function can be derived.

Another definition of S-function was proposed for flexibility [10]. In the following equation x is a grey level of input image a, b, c are the random parameters which are used to determine shape of S function further with this random points hypothesis of canny is evaluated. In the basic definition of S function the value of x is evaluated between a, a and b, b and c, and c itself. The hypothesis of canny is generated using random values which are calculated using the mean, variation and standard deviations. The lower threshold is considered as mean – variance and higher threshold is mean + variance. The definition of random parameters are represented in integral form as follows:

$$\left.\begin{aligned} f(x) &= \int_x^a x\,dx \\ f(x) &= \int_a^b \frac{(x-a)^2}{(b-a)(c-a)} x dx \\ f(x) &= \int_b^c 1 - \frac{(x-c)^2}{(c-b)(c-a)} x dx \\ f(x) &= \int_x^c 1\,dx \end{aligned}\right\} \quad (1)$$

Few works was reported on image segmentation using membership functions [11-13]. A fuzzy based trapezoidal membership function of mamdani type FIS was proposed by E. Boopathi Kumar et al [11] for the edge detection process. They used 2*2 masks with 16 rules in the fuzzy set to detect edges of the image. The result shows that the trapezoidal membership function reveals better edge detection than compared to triangular edge detection method.

Vehicle image edge detection was performed using Fuzzy logic based on triangular and trapezoidal membership function [12]. The authors used four inputs using two fuzzy sets and one output with one fuzzy set.

Based on these set of rules the output of fuzzy can be used to decide the particular pixel is on the edge or not. They observed that edge detection based on fuzzy logic is capable to identify thin and lucid vehicle edges with Gaussian filtering.

A fuzzy logic system was introduced for color image segmentation for classification of colors and segmentation of images with minimum number of rules and least error rate [13]. They used comprehensive learning particle swarm optimization (CLPSO) technique to determine best possible fuzzy rules and suitable membership functions. As the fuzzy system had less number of rules and less computational load the proposed method in the paper shows highest computational speed.

The present work focuses on the modification of traditional canny algorithm using S-membership function. The detailed statistical report was generated to compare the performances of traditional Canny and modified Canny using s-membership function.

IV. EXPERIMENTAL RESULTS

The improved canny algorithm is studied for six dissimilar grayscale images and it is observed that the more distinct marked edges was observed which have better visual appearance than the ground truth image. Thus the usage of fuzzy rule based membership functions in image segmentation provides enhanced edge detection. It has an extensive set of fuzzy conditions which might helps to identify the real edges more accurately with a very high efficiency.

The algorithm has been developed and simulated using MATLAB for the .png and .jpg images are to be considered. The assumed accuracy is 8 bits per pixel. The tested gray scale image files are of various sizes and dimensions.

Edge mapping have been developed using different evaluation methods [14]. Comparison of an edge map can be obtained by the detection of edges [14]. Various statistical indices such as true positive (TP) indicates correctly marked edge pixels; false positive (FP) classifies the quantity of erroneously detected pixels; and the number of edge pixels that were not categorized as edge pixels called as false negative (FN). From the above-mentioned parameters, the following statistical measures have been derived:

The percentage of pixels that were correctly detected (P_{CO}) can be calculated using the following equation

$$P_{CO} = \frac{TP}{\max(N_I, N_B)} \qquad (2)$$

where N_I corresponds to the total number of edge values of the groundtruth image and N_B the total number of detected edge points. The percentage of not detected pixels can describe as (P_{nd}):

$$P_{nd} = \frac{FN}{\max(N_I, N_B)} \qquad (3)$$

The fraction of pixels that were incorrectly detected as edge of the pixels, i.e. the percentage of false alarm (P_{fa}):

$$P_{fa} = \frac{FP}{\max(N_I, N_B)} \qquad (4)$$

The Pratt's figure of merit (FOM) is another useful measure to evaluate the accuracy of the edge location by the deviation of the detected edge points from an ideal edge. FOM utilizes the distance among all groups of points which results to measure, with much accuracy, the resemblance among two contours [15]. The Pratt's figure of merit can be defined as:

$$IMP = \frac{1}{\max(N_I, N_B)} \sum_{1}^{N_B} \frac{1}{1+\alpha \times d_1^{\,2}} \qquad (5)$$

Where d_i is the distance between an actual edge pixel and the nearest neighborhood edge pixel of the ground truth image and α is an empirical scaling constant. According to Pratt [15] the optimal value of α was chosen to be 1/9.

The FOM of Pratt (IMP) signifies the edge quality and gives extensive details about the distances of the edges. This is treated as relative measure varies in the range of 0 to 1. The maximum value of this parameter indicates that the edges detected are coincided with the ground truth.

The values of the parameters stated in the equations (2), (3) and (4) may fall in the range between 0 and 1. The suitable values of the indices P_{nd} and P_{fa} is 0 and P_{CO} will be 1 for best edge detection techniques. The combination of statistical indices specified by the equations 2, 3 and 4 together with the IMP parameter, a new global index parameter can be defined as Euclidean distance. The optimal values of the coordinates can be realized by the indices P_{CO}, IMP, P_{nd} and P_{fa} to evaluate Euclidean distance (d^4_{f2}) in R4 to the point P. The distance to this point can be obtained by the following equation:

$$d^4_{f2} = \sqrt{(P_{CO}-1)^2 + (IMP-1)^2 + P_{nd}^2 + P_{fa}^2} \qquad (6)$$

V. RESULTS AND DISCUSSION

The proposed method was tested with different grayscale images. Figure 1 shows the grayscale images of the algorithms such as traditional canny and the modified Canny using S-membership function. It was observed that the output images of the proposed algorithm provide much more clearly marked edges and have improved visual clearance. Usually the Fuzzy sets contains exhaustive conditions that provides to extract the edges at high efficiency [16].

Fig.2 (a) to (h) shows the variation of wide number of statistical parameters obtained from the proposed method and traditional Canny for the selected gray scale images. The parameter variation for

different gray scale images signifies that the modified Canny with s-function shows significant improvement in the detection of edges than comparing to traditional Canny edge detection technique

Table 1 lists the experimental results and the evaluation metrics. From the table, it is evident that the statistical measures of the modified canny algorithm with s-function are better than the default Canny operator and the efficiency is clearly visible from the output images. The improved algorithm can provide a better image, which contains more information and had better clarity. The reason is that open and close morphology filter can remove noise, at the same time it retains the image edge strength and important detailed information about the image.

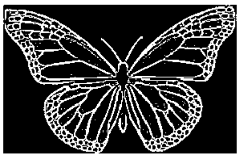
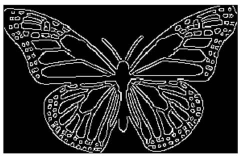
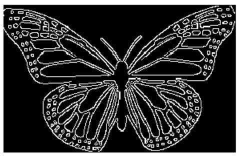
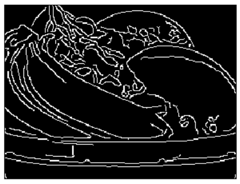
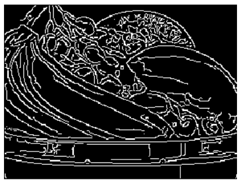
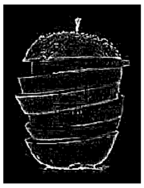
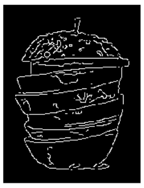
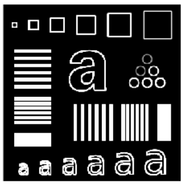
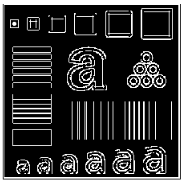
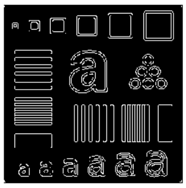
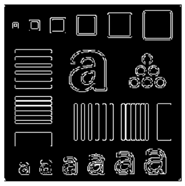
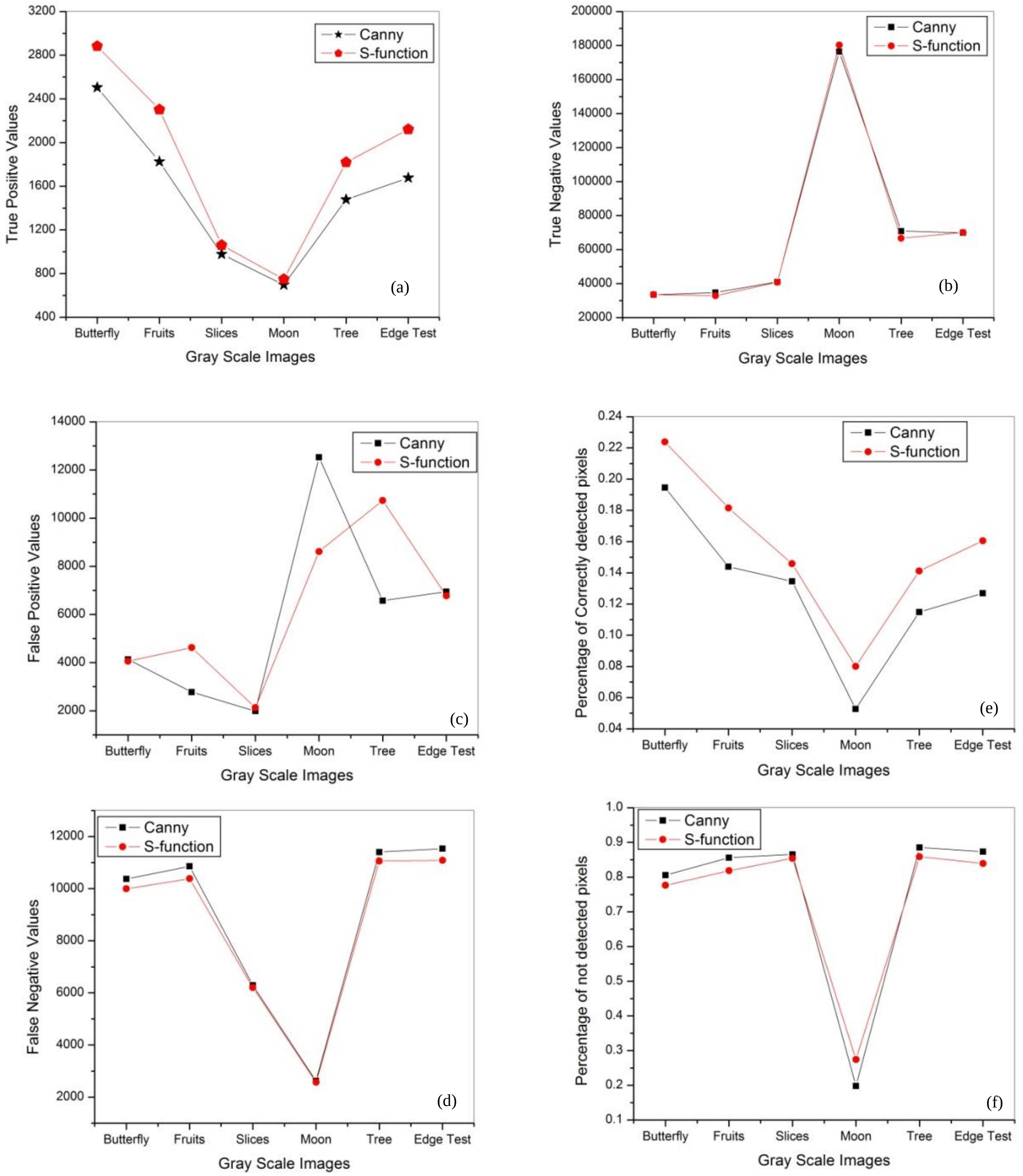
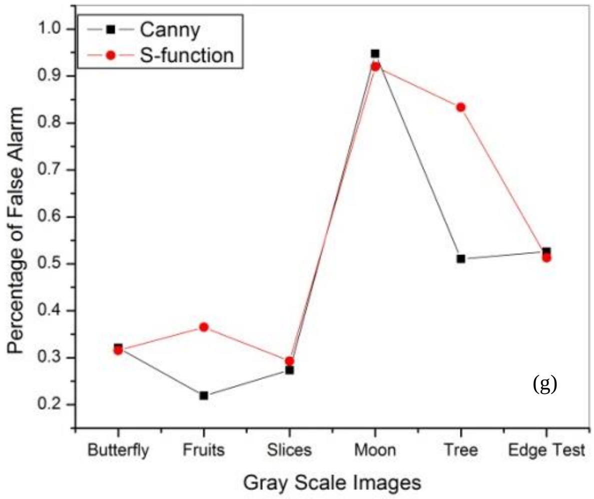
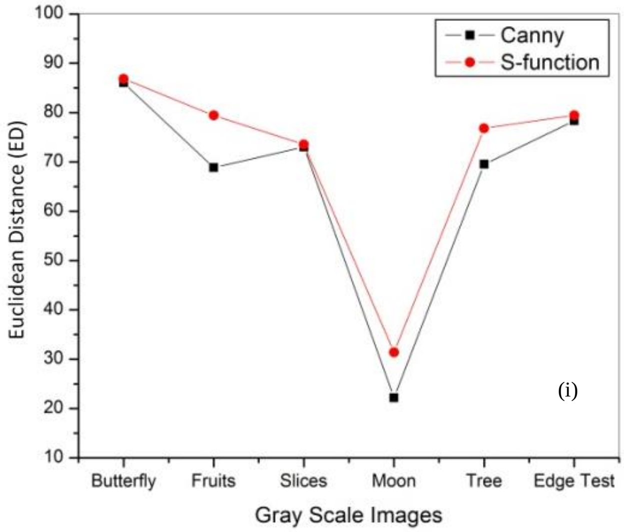
Image details	Original Image	Ground truth image	Default Canny	Modified Canny with S-function
Butterfly				
Fruits				
Slices				
Moon				
Tree				
Edge Test				

Fig. 1. Performance Test Results Of Traditional Canny And Modified Canny With S-MembershipFunction For Different Grayscale Images


(a)
True Positive Values
Gray Scale Images
Canny
S-function
Butterfly
Fruits
Slices
Moon
Tree
Edge Test
3200
2800
2400
2000
1600
1200
800
400
(b)
True Negative Values
Gray Scale Images
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
(c)
False Positive Values
14000
12000
10000
8000
6000
4000
2000
(e)
Percentage of Correctly detected pixels
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
(d)
False Negative Values
(f)
Percentage of not detected pixels
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1





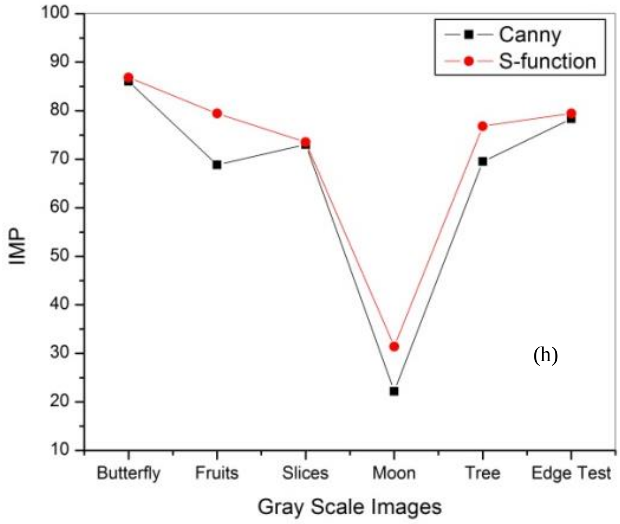


Fig. 7 Variations Of Statistical Parameters Of Different Grayscale Images

Images/ Statistical parameters		 Butterfly.png	 Fruits.png	 Slices.png	 moon.png	 Trees.jpg	 Edge test.png
TP	Canny	2505	1826	978	697	1478	1677
	S-function	2882	2302	1060	749	1819	2121
TN	Canny	33469	34787	40979	176401	70846	69846
	S-function	33540	32936	40840	180312	66685	70018
FP	Canny	4133	2775	1988	12527	6572	6945
	S-function	4062	4626	2127	8616	10733	6773
FN	Canny	10371	10858	6290	2621	11404	11532
	S-function	9994	10382	6208	2569	11063	11088
PCO	Canny	0.194548	0.143961	0.134562	0.052707	0.114734	0.126959
	S-function	0.223827	0.181488	0.145845	0.079979	0.141205	0.160572

PND	Canny	0.805452	0.856039	0.865438	0.198200	0.885266	0.873041
	S-function	0.776173	0.818512	0.854155	0.274319	0.858795	0.839428
PFA	Canny	0.320985	0.218780	0.273528	0.947293	0.510169	0.525778
	S-function	0.315471	0.364711	0.292653	0.920021	0.833178	0.512756
IMP	Canny	86.041149	68.841539	73.027336	22.186230	69.518537	78.335308
	S-function	86.826189	79.417963	73.538111	31.371457	76.818180	79.437643
ED	Canny	85.049383	67.852692	72.038254	21.229469	68.531873	77.346950
	S-function	85.833788	78.427354	72.548758	30.400552	75.832484	78.448302

Table 1. The Objective Evaluation Comparison Of Various Gray Scale Images Using Conventional Canny And Improved Canny Using S-Function.

VI. CONCLUSION

Canny algorithm was improved based on s-membership function is presented in this paper. Randomization of threshold values was achieved through s-membership function. The gray scale images were analyzed using default Canny and modified Canny through detailed statistical result. The output images reveal that the proposed algorithm can effectively realize the image edge extraction and provide accurate information for image measurement. The gray scale images obtained by modified Canny using s-membership function shows detailed marked edges and superior statistical performance.

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