Highly-Performed Fuzzily-logicized Edge Detecting Algorithm for Noisy Handwritings

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Abstract:

The main targets for using the edge detection techniques in image processing are to reduce the number of features and find the edge of image based-contents. In this paper, comparisons have been demonstrated between classical methods (Canny, Sobel, Roberts, and Prewitt) and Fuzzy Logic Technique to detect the edges of different samples of image's contents and patterns. These methods are tested to detect edges of images that are corrupted with different types of noise such as (Gaussian, and Salt and pepper). The performance indices are mean square error and peak signal to noise ratio (MSE and PSNR). Finally, experimental results show that the proposed Fuzzy rules and membership function provide better results for both noisy and noise-free images.

Keywords: Classical edge detection, Edge detection, Fuzzy logic, Image noise, Image processing.

Introduction:

The edge detection used to find the boundary pixels of objects resident in the image in order to reduce the data of features. There are classical methods used generally to find the edges of image contents (Sobel, Canny, Roberts, and Prewitt) and these methods usually operate depending on a pair of convolution kernels (3x3) [1,2]. These kernels are used to convolve the image by moving the mask kernel over pixels with respect to the center of mask represented as pivot pixel for other eight neighbor pixels. Below, definition equations and operators concepts for classical methods are presented.

Sobel Operator:

This operator consists of the following convolution kernel. The kernel is used by applying for an image and get measurements of the gradient in both orientations (Gx and Gy) and these components combined to produce the magnitude of the gradient in any neighborhood pixel. In equ.(1) is the form of gradient magnitude is given by following [3]

$$|G| = |G_X| \ |G_Y| \tag{1}$$

The convolution kernel of Sobel operator is shown in Table-1.

Table 1-Convolution kernel of Sobel operator

-1	0	+1
-2	0	+2
-1	0	+1

+1	+2	+1
0	0	0
-1	-2	-1

Canny operator:

Canny operator[4] has three criterions as described below.

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- Convolves an image f(m,n) by applying a Gaussian function
- Find edge strength, and gradient strength at each point
- Find edge direction
- Relate the edge direction to trace an image
- Apply non-maximum suppression for gradient magnitude image.
- Apply two thresholds Th1 > Th2, if magnitude > Th1 then output is edge, else if magnitude > Th2 then candidate
- Hysterias: Find all the candidates located in neighbors in gradient direction. In equ.(2) and equ.(3) is the formula of the Canny operator.

$$g(m,n) = G(m,n) * f(m,n) \qquad (2)$$
$$G_\sigma = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[-\frac{m^2+n^2}{2\sigma^2}\right] \qquad (3)$$

Where m and n represents current pixel of image, σ is relative to the highest value of the gradient magnitude of the image.

Robert operator:

This operation is measured as uncomplicated calculation which is 2D spatial gradient moves over an image. The output values of the pixels get from this operator represented the probable absolute magnitude of the spatial gradient of the input image at that point. This operator has consists convolution kernel of (2x2) as shown in Table-2 [5].

Table 2-Convolution kernel of Robert operator

1	0
0	-1

0	1
-1	0

Prewitt Operator:

This operator is used to detect both sides of edge vertically and horizontally in an image. The convolution kernel has designed as (3x3) to detect gradient in both sides as shown in Table-3 [6].

Table 3-Convolution kernel of Prewitt operator

| -1	0	+1
-1	0	+1
-1	0	+1

+1	+1	+1
0	0	0
-1	-1	-1

Fuzzy logic for edge detection:

One of the recent techniques that are used for edge detection in image processing is fuzzy logic [7,8,9]. This kind of technique is attractive to researchers because it can deal with image processing uncertainties[10].The detection procedure has three stages that are determined as image data (coding and decoding). In this paper, Fuzzy membership functions that represent input and output are triangles[11], many membership functions of different shapes were tested, the ones that give the satisfactory performance are shown in Figure-1.
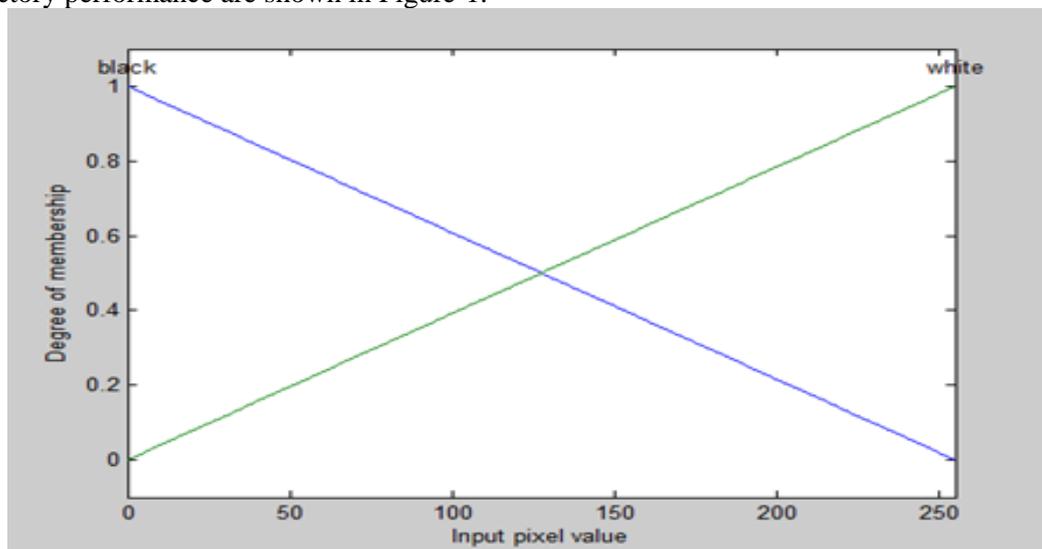
(A)
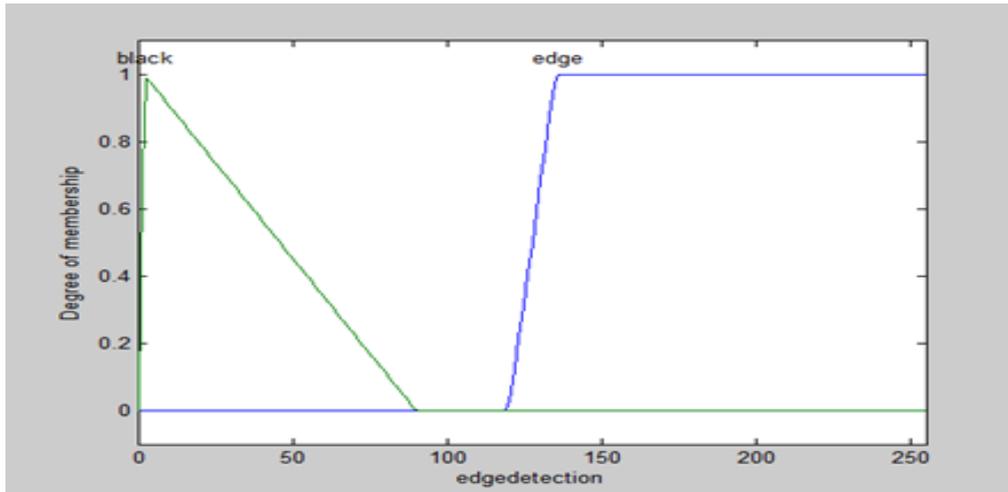
(B)

Figure 1-Membership function(A)Input (B)Output

The proposed design of FIS consists of four inputs and one output. the inputs are represented as (P1, P2,P3, and P4) that represents the pixel values of convolution kernel (2×2) as shown in Table-4 [12].

Table 4-Convolution kernel for input and output

P1	P2
P3	P4
	P4 out

Proposed system:

In this proposed approach, fuzzy algorithm basically has the usual fuzzy logic steps as some fuzzy edge detection approaches that are mentioned earlier. We've improved the detection of edges found in the image by selecting different membership functions, especially for the output. The selection of output membership functions is very important because of uncertainties that appear in images such as noise. Therefore, it is important to choose a suitable membership function and yet a fuzzy edge detection system that can distinguish between real edges and noise pixels. The main purpose is to design an edge detection system that can extract edges.

Results Analysis:

The test images are handwritten signatures which have a variety of contents (curves, angles, smooth line and hard line) for testing the proposed work. In the first phase (preprocessing), the input image is converted to grayscale which takes less time of processing than color format, in addition, a rescale has done on the grayscale image to fix size (256x256). Table-5 depicts the original noise free image samples and those samples after adding "Gaussian and Salt and Pepper noise".

Table 5-Original noise free and noisy image samples

noise	Sample)1(	Sample)2(
Original noise free		
Gaussian		
Salt & Pepper		

The performances of classical edge detection methods and fuzzy logic method are compared and

tested first for noise free images. Then two types of noise are added to image samples and the edge detection performances are evaluated using "Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR)". Informatics metric MSE and PSNR equations are described in formulas (4 and5) respectively.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \tag{4}$$

$$PSNR = 10.log_{10}\left(\frac{maxI^2}{MSE}\right) \tag{5}$$

Where i and j represent a current pixel of image, m and n represent height and width. I is the source image and K is the image compared with.

Table-6 shows the edge detection results for free of noise images. It is clear that fuzzy technique produces clearer and brighter edges as compared to conventional methods results.
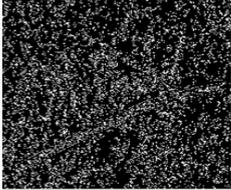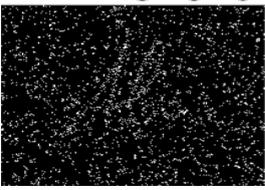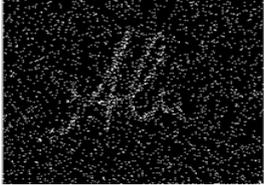
Table 6-Edge detection of noise free samples
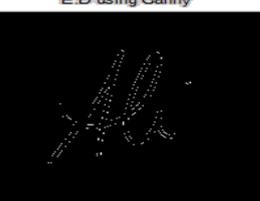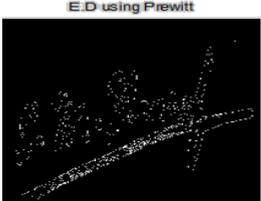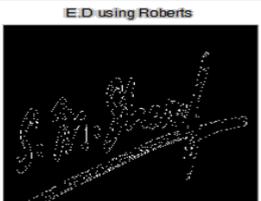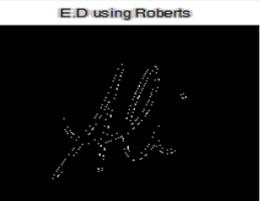
Method	Sample 1	Sample 2
Sobel		
Canny		
Prewitt		
Roberts		
Fuzzy logic		

Edge detection of images corrupted with Gaussian noise edge detection of images:
Gaussian noise of zero mean and 0.001 variance has been applied to the same image samples, in edge detection phase, a comparison between classical four types and fuzzy logic approach is depicted in Table-7.

Table 7-Edge detection of images corrupted with zero mean and 0.001 variance Gaussian noise.
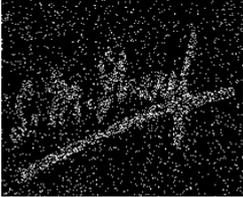
Method	Sample 1	Sample 2
Sobel		
Canny		
Prewitt		
Roberts		
Fuzzy logic		

From the table we conclude that the system couldn't remove Gaussian noise, however, the edge detection process produces clearer edges as compared to classical techniques. Finally, an informatics metric has been calculated to find the performance of proposed and classical methods. The comparison has been used on both noisy and free noise samples of images and between classical methods (Canny, Sobel, Prewitt, and Roberts) and fuzzy logic. The performance of the edge detection process is evaluated using MSE and PSNR and compared for classical methods and fuzzy logic method. The results are depicted in Table-8 contents the MSE results, and Table-9 contents PSNR results. The results show that Sobel method gives the lowest MSE and highest PSNR among other methods. However fuzzy edge detection technique produces the brighter visual appearance as shown in Table- 8.

Table 8-The MSE of edge detection methods for   images methods for images corrupted with Gaussian noise.

Methods	MSE sample 1	MSE sample 2

Sobel	0.0051	0.0013
Canny	0.0118	5.18e-04
Prewitt	0.0071	0.0014
Roberts	0.0069	0.0017
Fuzzy logic	0.0109	0.0035

Table 9-The PSNR of edge detection methods for images corrupted with Gaussian noise.

Methods	PSNR sample 1	PSNR sample 2
Sobel	71.0469	77.0231
Canny	67.3984	80.9865
Prewitt	69.6214	76.6334
Roberts	69.7596	75.8034
Fuzzy logic	67.7404	72.7163

Edge detection of noisy images:

The previous tests are repeated with a different type of noise which is called "salt and pepper". The results of edge detection of images corrupted with this noise of density 0.0045 (which means that 0.45% of the image is corrupted) are shown in Table-10. The results of Table-10 clearly pointing the superiority of the proposed filters to those of conventional ones that are sensitive to noise.

Table 10-MSE for edge detection when adding salt and pepper noise of density 0.0045 to images

Methods	MSE Sample 1	MSE Sample 2
Sobel	0.0926	0.0844
Canny	0.1824	0.1788
Prewitt	0.1543	0.1481
Roberts	0.0491	0.0431
Fuzzy Logic	0.0017	9.46e-04

The fuzzy method produces better edge detection without the need for filtering the noise before edge detection process. Informatics metric MSE and PSNR for both classical and fuzzy logic for sample images are discussed in Tables-(11 and 12) where Salt and Pepper noise filter applied with density 0.0045. Then the performances of the previous methods were tested by increasing the added salt and pepper noise density to 0.045 which means that 4.5% image is corrupted. The MSE and PSNR results are shown in Tables-(13 and 14).

Table 11-Edge detection of images corrupted with salt and pepper noise with density 0.0045 to images.
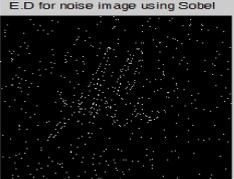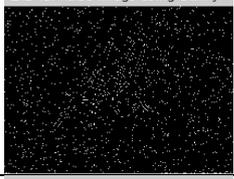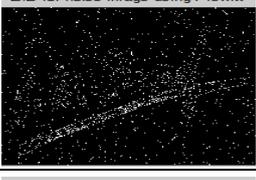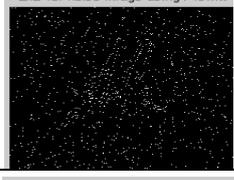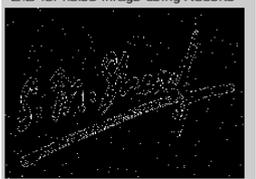
Method	Sample (1)	Sample (2)
Sobel	E.D for noise image using Sobel	E.D for noise image using Sobel
Canny	E.D for noise image using Canny	E.D for noise image using Canny
Prewitt	E.D for noise image using Prewitt	E.D for noise image using Prewitt
Roberts	E.D for noise image using Roberts	E.D for noise image using Roberts
Fuzzy logic		

Table 12-PSNR for edge detection when adding 0.0045 noise density to images

Method	PSNR sample 1	PSNR sample 2
Sobel	68.1800	68.4789
Canny	63.8493	64.2000
Prewitt	65.5472	65.6363
Roberts	71.0276	71.3653
Fuzzy logic	84.2544	90.2750

Table 13-MSE for edge detection when adding 0.045 noise density to images

Methods	MSE sample1	MSE sample2
Sobel	0.0099	0.0092
Canny	0.0268	0.0247
Prewitt	0.0181	0.0178
Roberts	0.0051	0.0047
Fuzzy logic	2.44e-04	6.10e-05

Table 14-PSNR for edge detection when adding 0.045 noise density to images

Method	PSNR sample 1	PSNR sample 2
Sobel	**58.4661**	**58.8695**
Canny	**55.5197**	**55.6068**
Prewitt	**56.2483**	**56.4256**
Roberts	**61.2159**	**61.7853**
Fuzzy Logic	**75.8424**	**78.3717**

The evaluation shows that fuzzy logic method produces the lowest MSE and highest PSNR among other edge detection methods for both noise densities. This means that fuzzy logic technique can detect edges of images corrupted with salt and pepper noise without the need to use filters to remove the noise from the image before the edge detection process.

Conclusion:

Fuzzy logic method produces bright and clear edge detection results for noisy images while classical methods couldn't give such good results because classical methods consider noise pixels as edges found in the image. Finally, comparison of the above results leads to the conclusion that fuzzy logic method can utilize the benefits of the Gaussian filter to give smooth and bright edges as shown clearly while classical methods could not detect the edges in such a good way. In general, fuzzy logic edge detection technique proves to be an effective edge detection method with a superior performance to that of the compared classical edge detection methods.

Future work:

The future work will be extended the presented 2D edge filtering model to be developed for a 3D grayscale edge filtering model [14-18] and 4D color edge filtering model for advanced bio imaging applications [19]. A breakthrough approach for handwritten alphabet machine recognition may be achieved via fuzzy entropy [20] and real-time character recognition algorithm [21].

References

1. Hasan SK. **2005**. *FPGA* implementations for parallel multidimensional filtering algorithms, Newcastle Upon Tyne: University of Newcastle (Doctoral dissertation, PhD thesis).
2. Hasan S, Boussakta S, Yakovlev A. **2011**. FPGA-based architecture for a generalized parallel 2-D MRI filtering algorithm. *American Journal of Engineering and Applied Sciences.* 2011; **4**(4): 566-75.
3. Hasan S. and Jumaa SS. **2018**. Implementation of Fuzzy Logic Techniques in detecting ddges for noisy images. *Journal of Fundamental and Applied Sciences*. 2018; **10**(5S).
4. Canny J. **1987**. A computational approach to edge detection. In Readings in computer vision 1987 Jan 1 (pp. 184-203). Morgan Kaufmann.
5. Juneja M. and Sandhu PS. **2009**. Performance evaluation of edge detection techniques for images in spatial domain. *International journal of computer theory and Engineering*. 2009 Dec 1; **1**(5): 614.
6. Muthukrishnan R and Radha M. **2011**. Edge detection techniques for image segmentation. *International Journal of Computer Science & Information Technology*. 2011 Dec 1; **3**(6): 259.
7. Bharti S, Kumar S. **2013**. An edge detection algorithm based on fuzzy logic. *International Journal of Engineering Trends and Technology*. 2013 Mar; **4**(3).
8. Kaur EK, Mutenja V. and Gill EI. **2010**. Fuzzy logic based image edge detection algorithm in MATLAB. *International Journal of Computer Applications*. 2010 Feb; **1**(22): 55-8.
9. Hasan S. and Amer A. **2018**. Applying fuzzy artificial neural network OSPF to develop smart routing protocol algorithm. *Journal of Fundamental and Applied Sciences*. 2018; **10**(4S): 659-62.
10. Alshennawy AA. and Aly AA. **2009**. Edge detection in digital images using fuzzy logic technique. .World Acade my of science, engineering and technology. 2009 Mar 24;51:178-86
11. Vikram K, Upashyaya N, Roshan K. and Govardhan A. **2010**. Image edge detection. Special Issues of *international Journal of Computer Science and Informatics* (IJCSI). .2;2010
12. Vyas R. and Garg G. **2012**. Face recognition using feature extraction and neuro-fuzzy techniques. *International Journal of Electronics and Computer Science Engineering.* 2012; **1**(4): 2048-56.
13. Jain R, Kasturi R. and Schunck BG. **1995**. *Machine vision*. New York: McGraw-Hill; 1995 Mar 1.
14. Hasan S, Boussakta S. and Yakovlev A. **2010**. Improved parameterized efficient FPGA

implementations Improved of parallel 1-D filtering algorithms using Xilinx System Generator. InThe 10th IEEE International Symposium on Signal Processing and Information Technology 2010 Dec 15 (pp. 382-387). IEEE.

15. Hasan S, Boussakta S. and Yakovlev A. **2011**. Parameterized FPGA-based architecture for parallel 1-D filtering algorithms. InInternational Workshop on Systems, Signal Processing and their Applications, WOSSPA 2011 May 9 (pp. 171-174). IEEE.

16. Hasan S. **2016**. Performance-vetted 3-D MAC processors for parallel volumetric convolution algorithm: A 256× 256× 20 MRI filtering case study. In2016 Al-Sadeq International Conference on Multidisciplinary in IT and Communication Science and Applications (AIC-MITCSA) 2016 May 9 (pp. 1-6). IEEE.

17. Humaidi AJ, Hassan S. and Fadhel, MA. **2018**. Rapidly-fabricated nightly-detected lane system: An FPGA implemented architecture. *The Asian International Journal of Life Sciences*. 2018; **16**(1): 343-355.

18. Humaidi AJ, Hassan S. and Fadhel MA. **2018**. FPGA-based lane-detection architecture for autonomous vehicles: A real-time design and development. *The Asian International Journal of Life Sciences*.2018; **16**(1): 223-237.

19. Humaidi AJ, Hasan S. and Al-Jodah AA. **2018**. Design of Second Order Sliding Mode for Glucose Regulation Systems with Disturbance. *International Journal of Engineering & Technology.* 2018;**7**(2.28): 243-7.

20. Ar-Ramahi SK. **2008**. A Fuzzy Recognition Model for Arabic Handwritten Alphabet. *Journal of Engineering* .900-2891:(3)14;2008

21. Hasan S. and Amer A. **2018**. Real-time vehicle ID identification using parallel-joining wireless sensor network. *Journal of Fundamental and Applied Science*s. 2018; **10**(4S): 663.