An Edge Detection System for Polluted Images by Gaussian, Salt and pepper, Poisson and Speckle Noises

S.Muhammad Hossein Mousavi
Department of Computer Engineering
Bu Ali Sina University
Hamadan, Iran
h.mosavi93@basu.ac.ir

Marwa Kharazi
Department of Computer Engineering
Bu Ali Sina University
Hamadan, Iran
m.alkharaz93@basu.ac.ir

Abstract

Due to the problems which noises may cause in receiving, transmission and processing images, and the problems that traditional edge recognition methods such as: Canny, Zerocreoss, Log, Roberts, Prewitt and Sobel have in relation to these noises, especially Gaussian, Salt and Pepper, Poisson and Speckle, we decided to design a system which is not only an edge detection method, but in the case, facing different noises, is able to indicate least of sensitivity. This system comprises three section, which initially divide the RGB image to its constituent colours, and then applies a filter to them in order to make it smooth (without changing the real position of the edges). In the next section, a new filter is employed to display the edges, and in the last section, a post-process will takes place on the output binary image for eliminating superfluous spots. The acquired results of comparison of this system with traditional edge detection operators indicates the high efficiency and robustness of it, against different noises. Also in order to statistically validation, we benefit from PSNR, MSE and SSIM factors. Even statistical results indicate the high similarity of noisy edge detected images and non-noisy edge detected images in the proposed system.

Keywords: Image Processing, Edge Detection, Noise, Binary Image, Filter

I. INTRODUCTION

The edge detection is one of the most important aspects of the image processing, image analysis and statistical pattern recognition. The significance of the edges is in their aspect in which they provide a perfect perspective of the object in the image. With the use of the object edges, it is possible to obtain the sufficient data on image analysis. The success in the object recognition stage depends on the accuracy of the edge detection. In general terms, the following factors must be considered in the recognition stage: first, no edge should be destroyed as much as possible, and secondly, no edge should be chosen wrongly, and thirdly, the edge must be place in its right position [1]. It is obvious, image pollution using noises, makes problems in receiving, transferring and processing images. If there is no solution eliminating the noises, they cause undesirable edges, which are not real edges. As a result, it causes uneven edges, thus the main form of objects is lost. Using image smoothing methods it is possible to reduce noises to some extent, but this action causes transforming the real position of the edge. In order to resolve this problem, this paper provides an edge detection system for polluted images by different noises, which finally after passing the stages mentioned in section three, the real position of the edges will maintain and the effect of noises in final output, will be significantly reduced.

II. PRIOR WORKS

Most of the classic edge detection operators such: Canny [7], Zerocross [6], Log [5], Roberts [5], Roberts [4], Prewitt [3], Sobel [2] are the examples of Gradiant-based edge detection methods. These operators, due to being so sensitive to noises, are not suitable for the main stage of image processing. Recently, a variety of different methods on edge detection of noisy images (without the effect of noise on the edge), has been innovated. Some of them are: wavelet transform [8], mathematical morphology method [9], neural networks [10], Fuzzy method [11] and etc.

III. PROPOSED SYSTEM

In this system, an edge detection method for detecting the edge of noisy and non-noisy images is proposed. Phases are: initially RGB image divide to the three constituent channels of R, G and B. Then we use Median filter on each channel, applying a definite value [12]. Then attach all the channels together to achieve a new RGB image. The aim of applying Median filter in this fashion is to achieve a kind of special smoothing of the image, which can deal with all sort of noises. It should be considered, applying this filter only to one channel and on the gray image would not achieve the desired result. Selecting pixels by the Median filter is presented in figure 1. In the next stage, the smoothed image becomes sharpened by the Unsharp Mask filter [13]. Table 1 presents the filter used for edge sharpening. After edge sharpening, for edge detection, the output image will be sent to the gray level. Next, it is the time for applying the proposed edge detection filter, which is a 3*3 matrix. It will be applied to the image from four sides. This filter is presented in formula 1. This filter after smoothing and sharpening the image causes very beautiful sharp edges, and also causes the noise not being seen in the output image. In order to eliminate the superfluous noises in output binary image, a post-processing action is applying to two dimensions of the image. This happens for eliminating the possible noises. Finally, for thinning the edges, using Hit or Miss Morphology system, the final output is achieved. This system is implemented by Matlab. The flowchart of the proposed system is presented in Figure 2.

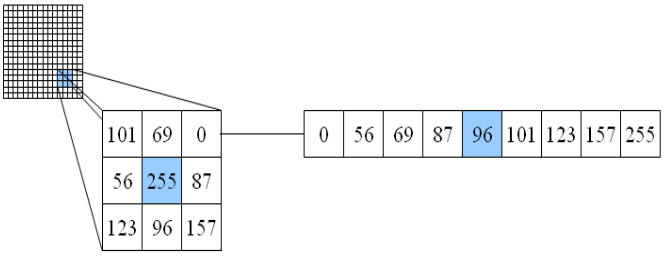

Fig. 1. **How selecting pixels by the Median filter**

TABLE 1. SHARPENING FILTER, USED TO SHARPEN EDGES

0	1	0
1	-4	1
0	1	0

$$|\nabla f(x,y)|=|(0.6Z7+0.8Z8+1.2Z9)-(0.6Z1-0.8Z2-1.2Z3)| +|(1.2Z3+0.8Z6+0.6Z9)-(1.2Z1-0.8Z4-0.6Z7)| \quad (1)$$

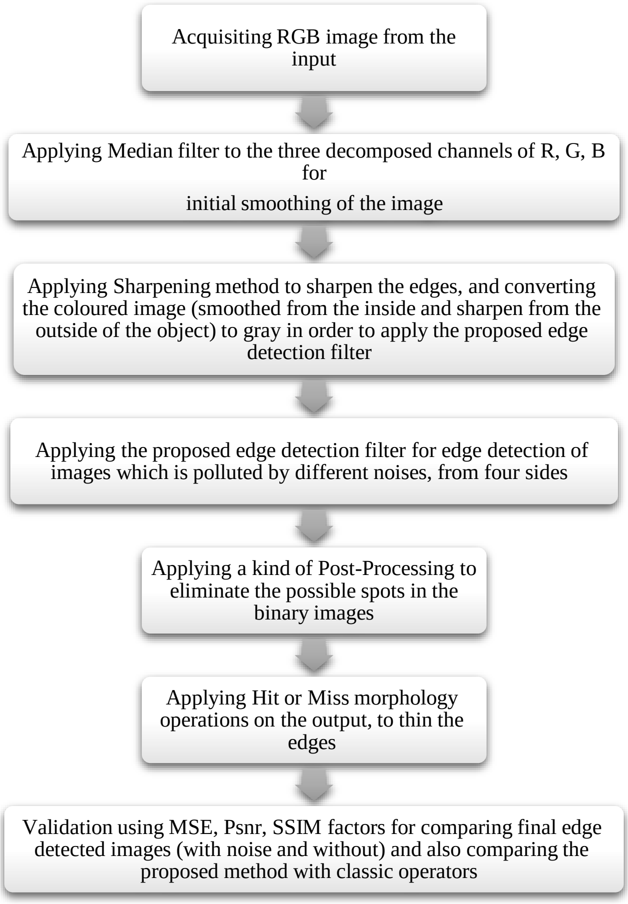

Fig. 2. **Procedure of the proposed edge detection method**

In order to apply this filter, first we apply the contents of Table I on a gray surface image. Then the matrix of the gray image must be subtracted from this filter. The final output will be displayed, having sharp edges. Table 2 is containing four filters; each apply to the image from two horizontal and vertical sides. Formula 1 implements only one of eight masks, and the Remaining seven filters can be implemented, with placing them in Formula 1 in relation to the Table 3. Figure 3 presents the general procedure of the proposed system, using an example.

TABLE 2. THE FOUR PROPOSED FILTER FOR EDGE DETECTION

-1.2	-0.8	-0.6		1.2	0.8	0.6
0	0	0		0	0	0
1.2	0.8	0.6		-1.2	-0.8	-0.6
1.2	0	-1.2		-1.2	0	1.2
0.8	0	-0.8		-0.8	0	0.8
0.6	0	-0.6		-0.6	0	0.6
-0.6	-0.8	-0.1		0.6	0.8	0.1
0	0	0		0	0	0
0.6	0.8	0.1		-0.6	-0.8	-0.1
0.1	0	-0.1		-0.1	0	0.1
0.8	0	-0.8		-0.8	0	0.8
0.6	0	-0.6		-0.6	0	0.6

TABLE 3. AUXILIARY TABLE FOR IMPLEMENTATION OF (1)

Z1	Z2	Z3
Z4	Z5	Z6
Z7	Z8	Z9

IV. TESTS AND VALIDATION

For validating the acquired result, we use the MSE, PSNR, SSIM factors. Formula 2, 3 and 4 are respectively used to implement these factors. The value of MSE [14] must be less and the value 0 is the best, meaning there is no error, or indicating the perfect similarity between input image and the reference image. PSNR [15] is another one of these factors with a number usually between 5 to 50. The more this value is, the better, and the high similarity of the input image with reference can be estimated by a number like 50. The next factor is SSIM [16], which is a number between 0 and 1. The higher this value is, the better result exists. The best result is something between 0.9 to 1.

$$MSE = \frac{1}{M \times N} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [X(i,j) - Y(i,j)]^2 \quad (2)$$

In which, X and Y are two arrays with the size of M*N. To any extent Y resembles X, the value of MSE will reduce.

$$PSNR = 10\log_{10} \frac{L^2}{MSE} \quad (3)$$

In which L determines the range of value, which a pixel could have. Its unit is DB, and has a limit of 50. The proper value is between 20 and 50.

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + C1)(2\sigma_{xy} + C2)}{(\mu_x^2 + \mu_y^2 + C1)(\sigma_x^2 + \sigma_y^2 + C2)} \quad (4)$$

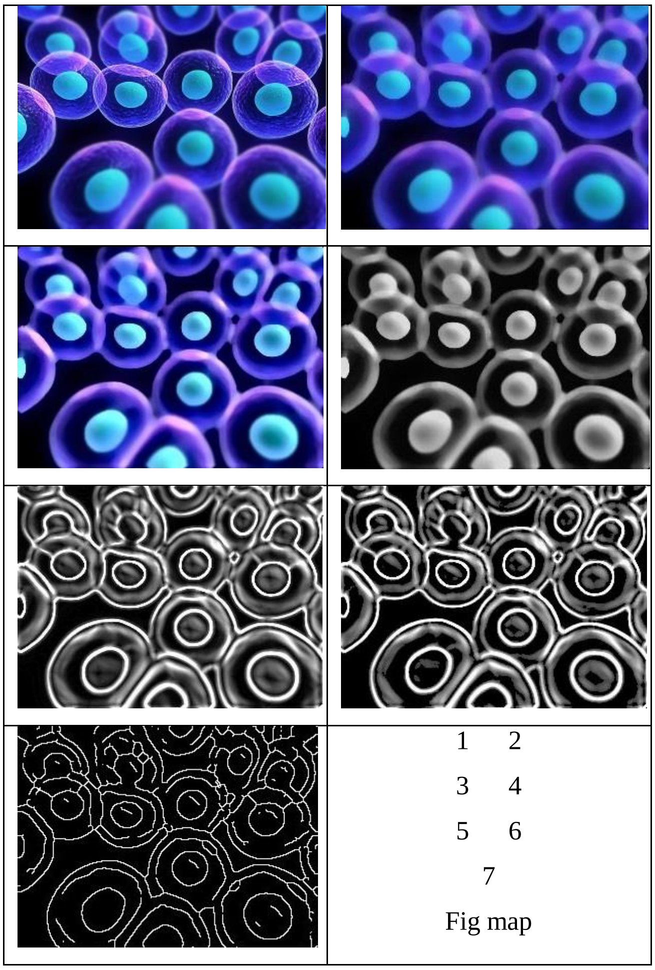

Fig. 3. **the visual procedure of the edge detection system (from left to right) based on Fig 2 (1)**

In order to validate the results, for all the tests, a human brain image with size of 300*300 is used. In figure 4 this image as RGB image, Gray-Scale image; with Gaussian[17], Salt & Pepper, Poisson and Speckle noises, respectively from left to right and up to down is presented. The values for the Gaussian parameter is zero for the mean, and 0.05 for the standard deviation. Also, the noise density for Salt and Pepper-noise is 0.1 and variance of the Speckle-noise is determined 0.1. These values are used for all outputs.

The visual validation results of the proposed system on data of figure 4, and with given parameters, is observable in figure 5. Also, this paper presents the comparison results of the traditional and conventional systems, using the proposed system. It is obvious that the acquired results of the proposed system, in the same condition (value and the kind of the visual noise), are better than the tradition method. In the acquired output of the speckle noise by the proposed system, a very small amount of noise is observable. But, in general it can be said that this system is superior to all the prior methods. As figure 5 indicates, the weakest result relates to the operator Roberts, and the strongest is possessed by the proposed system. Canny from visual vantage point, stands on the second stage, but from statistical point of view, the situations is vice versa. Comparing with other approaches, the proposed system indicates least of sensitivity to different noises.

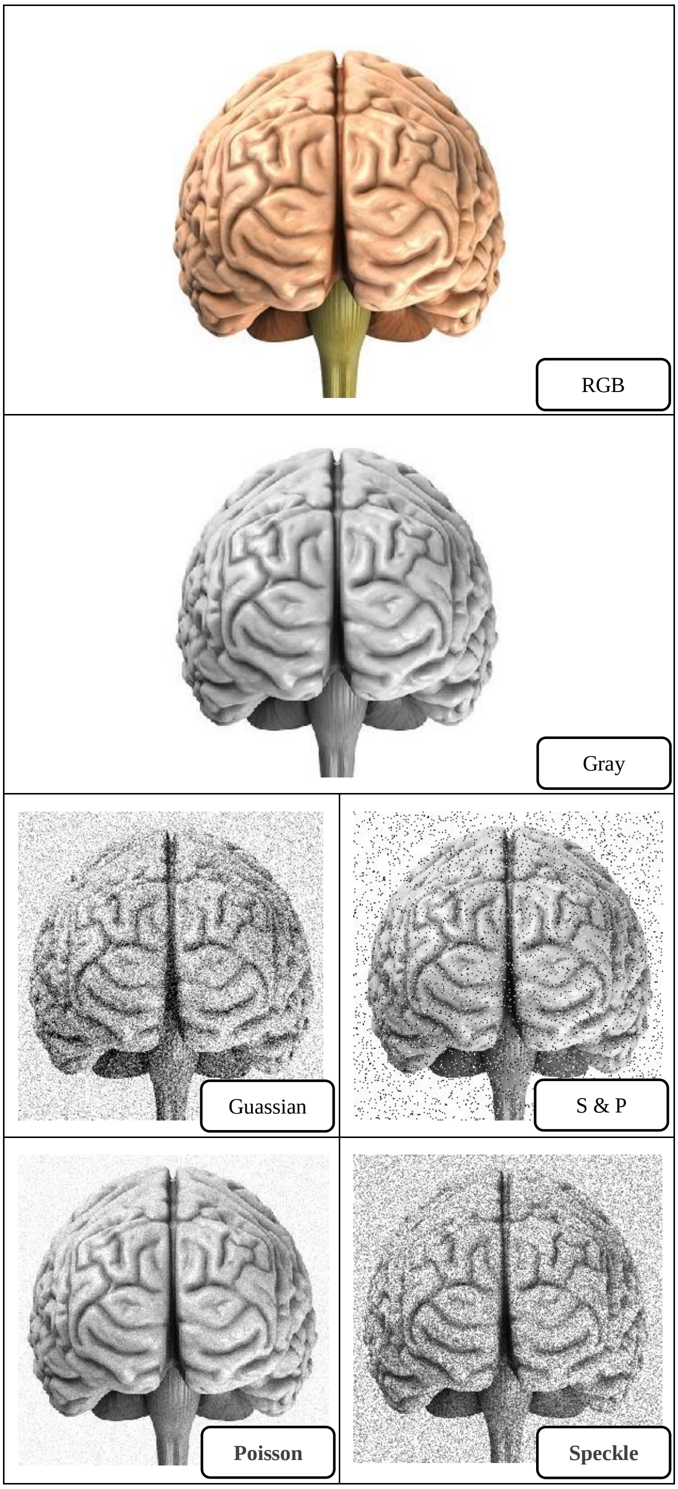

Fig. 4. **Test data for validation, an image of human brain (RGB, gray, with four different noises) (2)**

(1). http://biology.usf.edu/cmmb/images/cells2.jpg

(2). http://www.luminartsoft.com/wp- content/uploads/2016/08/large_accurate_human_brain_3d_model_obj_blend_b97bd84b-9bd7-49da-a584-9cd73e892596.jpg

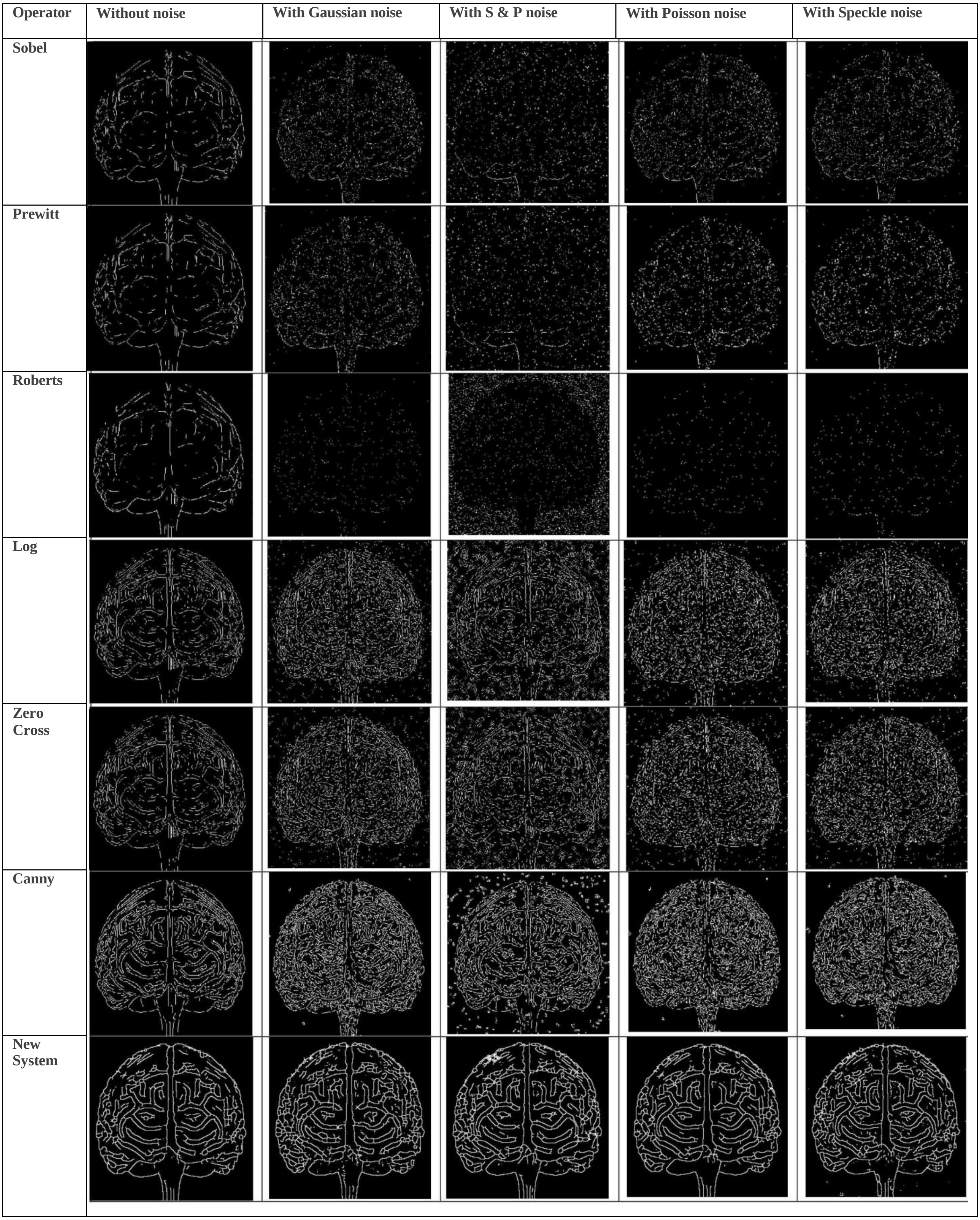

Fig. 5. **Proposed system results comparing with other traditional conventional operators, on different noises**

Acquired results of the Tables 4, 5 and 6 respectively relate to the MSE, PSNR and SSIM factors. These results have compared the functionality of the proposed system and the conventional edge detection operators. As MSE table indicates, the proposed system has had least of errors compared to all other operators. PSNR and SSIM tables also have had most of value in similar noisy condition, compared to other operators. This indicates the robustness of the proposed system to different noises. The best result in MSE relates to the salt and pepper noise with the error of 0.0190, and the best result in PSNR, with the value of 23.88 is registered for this noise. But the best value in SSIM table with 0.9615 is achieved for the Poisson noise. Due to a little difference in outputs in visual and statistical conditions, using both of them is essential. For instance, Robert operator, which in the visual condition presents an undesirable result, has a more proper result in statistical conditions. But, Canny, with a proper condition from visual vantage point, has an undesirable result in statistical situation. These result are acquired due to their more details not to the weakness of canny operator. It is obvious that Canny functions far better than Roberts. The proposed system possesses desirable results, from both vantage points in same conditions.

TABLE 4. MSE ERROR, RELATED TO THE MUTUALITY OF THE PROPOSED SYSTEM AND PRIOR METHODS TO THE DIFFERENT NOISES

MSE / Operators	Noise type	Gaussian noise	S & P noise	Poisson noise	Speckle noise
Sobel		0.0819	0.0516	0.0466	0.0994
Prewitt		0.0816	0.0511	0.0468	0.0985
Roberts		0.0956	0.0733	0.0637	0.1151
Log		0.1384	0.1612	0.0313	0.1562
Zerocross		0.1381	0.1609	0.0320	0.1573
Canny		0.1936	0.2080	0.0538	0.2543
New System		0.0732	0.0190	0.0244	0.0849

TABLE 5. PSNR RELATED TO THE MUTUALITY OF THE PROPOSED SYSTEM AND PRIOR METHODS TO THE DIFFERENT NOISES

PSNR / Operators	Noise type	Gaussian noise	S & P noise	Poisson noise	Speckle noise
Sobel		13.77	12.87	17.81	14.04
Prewitt		13.81	12.91	17.75	14.14
Roberts		11.28	11.96	10.16	10.09
Log		8.58	7.92	15.4	8.06
Zerocross		8.59	7.93	14.95	8.03
Canny		7.13	6.81	12.69	5.94
New System		14.53	23.88	23.56	14.32

TABLE 6. SSIM, RELATED TO THE MUTUALITY OF THE PROPOSED SYSTEM AND PRIOR METHODS TO THE DIFFERENT NOISES

SSIM / Operators	Noise type	Gaussian noise	S & P noise	Poisson noise	Speckle noise
Sobel		0.4196	0.3482	0.8230	0.4784
Prewitt		0.4235	0.3481	0.8196	0.4869
Roberts		0.3006	0.3995	0.6537	0.5211
Log		0.1400	0.1131	0.7487	0.1069
Zerocross		0.1432	0.1162	0.7443	0.1050
Canny		0.2649	0.1721	0.7542	0.1233
New System		0.7786	0.9576	0.9615	0.6038

V. CONCLUSION

The proposed system is not only a new edge detection approach, but is able to deal with different noises in digital images, and indicate the least of sensitivity. This happens in a condition in which, conventional edge detection methods, have a lot of sensitivity to different kind of noises. This system does not change the real position of the edges, which causes to use it in applied cases with the peace of mind. This system possesses the best results, in validated visual and statistical results against other conventional edge detection methods, in the same situation. With changing the proposed system, we are able to create a sort of image feature extraction method (this is of future works).

REFRENCES

[1] Jain, Anil K. Fundamentals of digital image processing. Prentice-Hall, Inc., 1989.

[2] Sobel, Irwin, and Gary Feldman. "A 3x3 isotropic gradient operator for image processing." a talk at the Stanford Artificial Project in (1968): 271-272.

[3] Prewitt, Judith MS. "Object enhancement and extraction." Picture processing and Psychopictorics 10.1 (1970): 15-19.

[4] Lawrence, G. ROBERTS. Machine perception of three-dimensional solids. Diss. Ph. D. Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 1963.

[5] Lindeberg, Tony. "Scale selection properties of generalized scale-space interest point detectors." Journal of Mathematical Imaging and Vision 46.2 (2013): 177-210.

[6] Haralick, Robert M. "Digital step edges from zero crossing of second directional derivatives." IEEE Transactions on Pattern Analysis and Machine Intelligence 1 (1984): 58-68.

[7] Canny, John. "A computational approach to edge detection." IEEE Transactions on pattern analysis and machine intelligence 6 (1986): 679-698.

[8] Shih, Ming-Yu, and Din-Chang Tseng. "A wavelet-based multiresolution edge detection and tracking." Image and Vision Computing 23.4 (2005): 441-451.

[9] Lee, James, R. Haralick, and Linda Shapiro. "Morphologic edge detection." IEEE Journal on Robotics and Automation 3.2 (1987): 142-156.

[10] Rajab, M. I., M. S. Woolfson, and S. P. Morgan. "Application of region-based segmentation and neural network edge detection to skin lesions." Computerized Medical Imaging and Graphics 28.1 (2004): 61-68.

[11] Akbari, A. Sheikh, and J. J. Soraghan. "Fuzzy-based multiscale edge detection (FWOMED)." (2003).

[12] Gonzalez, Rafael C., Richard E. Woods, and S. Eddins. "Digital Image Processing Using MATLAB, Prentice Hall."." Upper Saddle River, NJ (2003).

[13] MathWorks, January. "Image Processing Toolbox for Use with MATLAB: User's Guide." The MathWorks Inc (2003).

[14] Lehmann, Erich Leo, and George Casella. Theory of point estimation. Springer Science & Business Media, 2006.

[15] Huynh-Thu, Quan, and Mohammed Ghanbari. "Scope of validity of PSNR in image/video quality assessment." Electronics letters 44.13 (2008): 800-801.

[16] Wang, Zhou, et al. "Image quality assessment: from error visibility to structural similarity." IEEE transactions on image processing 13.4 (2004): 600-612.

[17] Barbu, Tudor. "Variational image denoising approach with diffusion porous media flow." Abstract and Applied Analysis. Vol. 2013. Hindawi Publishing Corporation, 2013.

[18] Schottky, Walter. "Über spontane Stromschwankungen in verschiedenen Elektrizitätsleitern." Annalen der physik 362.23 (1918): 541-567.

[19] Forouzanfar, M., and H. Abrishami-Moghaddam. "Ultrasound Speckle Reduction in the Complex Wavelet Domain." Principles of Waveform Diversity and Design, M. Wicns, E. Mokole, S. Blunt, R. Sfhneible, and V. Amuso (eds.), SfiTech Publishing (2010).