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Denoising CT Images using Median based Filters: a Review

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***Abstract*—medical imaging is one of the essential tools for evidence-based medical diagnosis. However, salt and pepper noise could corrupt the original image, reducing the overall image quality. Computed tomography (CT) images database were used. The filter execution and evaluation algorithm were implemented using MATLAB environment. This article was conducted to study the performance of four different median based filters standard median filter (SMF), adaptive median filter AMF, center weight median filter (CWMF), and progressive switching median filter (PSMF), when applied to medical images. Noise immunity and edge-preserving were evaluated to characterizing the filtrations processes, by means of statistical (texture) and mathematical measures Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Correlation Ratio (CORR), and Image Enhancement Factor (IEF) for noise reduction, and automatic edge detection as visual evaluation for edges. The results shown that the Adaptive Median Filter(AMF) can remove the salt and pepper noise from CT image, the AMF algorithm maintain the edge of the image and detail information of the objects, And the overall filters comparison indicates a quite effective noise removal and satisfactory performance of AMF among others.**

Keywords—medical image, comparative analysis, median filter, texture, edge detection.

I. INTRODUCTION

Digital imaging plays an important role in some medical practice especially in study the internal organs' anatomy and physiology abnormalities [1]. Medical image could be acquired by using advanced imaging equipment such as CT scan. Random disturbance of electron component or synchronization errors during digitization could results in development of impulse noise [2]. Most of The medical images were affected by several types of noise and distortion [2]. The affected image develops an obstacle in feature extraction, information analysis and object recognition [3]. Therefore, the first image preprocessing step is filtering the row image data [2] [3].

The dominant feature of a good image filtering model is that it should totally remove noise, as well as preserve edges and details [4]. Generally, there is no specific method for noise removal but each and every filtration approach has own advantage and limitation during the denoising process [5].preserving the detailed information in the medical images while processing and handling with them is a research field still being worked on.

many previous studies compromise the performance of median based filter is evaluated in non-medical images in the other hand medical image have detailed information must be preserved when filtered and processed because a small variation it would be misleading for physicians in decision making (diagnosis and treatment), here we want to compromise the performance and saving the critical medical information in these CT images.

Ognjen Magud et al., present in their work a method for removing salt and pepper noise from the ultrasound images using a modified median filter [6]. Amanpre Kauret al ET, Conduct evaluation for Salt and Pepper noise removal algorithm. Their method based on a sorted non-iterative median filter to suppress different density of salt and paper noise [7]. James Church et al presents the ability of modified Spatial Median Filter to remove noise and reconstruct the original image, they introduce two new filters and compare it to four other methods of denoising [8]. Several study evaluate the performance of non-linear techniques such as Standard median filter (SMF) [9], Adaptive median filter (AMF) [10],and progressive switching median filter (PSMF) [11].

The objective of this study is to investigate the performance of the above reviewed technique on CT image of the liver corrupted by impulse noise. The database was taken from atlas liver database website of washington university that contains a compehensive specterum of liver diseases and their imaging features [12]. The quality of the de-noised image and details reservation has been evaluated.

A. Impulse Noise In Medical Image

The impulse noise is autonomous of the pixels information and is indiscriminately scattered over the original image, in which some of the pixels in the image will be affected, while the rest of the pixels will remain unchanged [1]. Salt and pepper noise and the noise of random impulse noise have similar impulse mechanism [13]. The Salt and Pepper noise mess up the pixels alternatively between the pixel values of the extreme image. In medical images where the standard image display gray scale is 0-255In case of random-valued impulse noise, the noise model based on the probability of noise ratio to the pixel that been corrupted. With pepper noise and salt noise respectively for an impulse noise [14].

The presence of salt and paper noise in the medical image may be relatively high or low [11]. Due to this it degrades the image quality and causes some loss of image information details [11]. In this study the acquired images debased by Salt and Pepper noise.

B. Images Database

The processed image are liver CT images were taken from Liver Imaging Atlas web-based online reference - University of Washington. The image database is a free web-based reference of liver CT, MRI and ultrasound imaging for medical professionals that contain comprehensive spectrum of liver diseases and imaging feature [15].

C. Median Based Filter Review

1) Standerd Median Filter(SMF)

Standard Median Filter measures the average of intensity of the selected window and associates the value at the center [14]. The function was presented in [16].

2) Adaptive Median Filter (AMF)

Some of the limitation of traditional median filter it doesn't consider the variation of image characteristics. It automatically replaces the pixel value according the mechanism of SMF. While the adaptive median filter capable to adapt this behavior according to the characteristics of the image. The behavior mechanism of AMF inside the filter template was described in [17].

3) Center Weight Median Filter(CWMF)

The Center Weighted Median Filter manipulates the weight factors according to the size of the kernel and the corresponding information the filter is defined as:

$$g(p) = median \begin{cases} 2 \diamond f(r_c), \\ f(r) where\ r \in N_{d_{B},1}(r) \end{cases} \quad (1)$$

Where $\diamond$represent replication operator and $f(r_c)$ is gray level value of the center pixel [18].

4) Progrissive Switch Median Filter(PSMF)

The approach of this filter encompass of in two stages, firstly the impulse detection algorithm is used to generate a sequence of binary flag images to predict the noisy locations. And secondly, the noise filter was implemented through successive iterations [19]. Both the impulse detector and the noise filter are applied in iterative behavior and boundaries are updated to preserve the edges [16].

D. Enhanced Image Charctrization

Image evaluation was implemented to estimate the performance of each implemented filter. Texture analysis, mathematical analysis and visual inspection were implementing to scale the overall performance.

1) Texture Analysis

Six texture analysis algorithms were used to quantify the image texture content [9]. The drive features used to characterize the image texture were based on variable represent the intensity, histogram of the intensity levels and its distribution possibilities in the area. Calculated parameters indicates the following:

(a) the average of image intensity information (Mean), (b) the average image contrast variation (standard deviation), (c) the relative smoothness of the image intensity (Smoothness), (d) the degree of calculated a histogram similarity around the center (Third moment), (e) the overall image information consistency (Uniformity) and (f) the image randomness and variability Entropy(e). The mathematical expressions of the six features were presented in [9].

2) Mean Square Error (MSE)

Is a quantity used to measure how close as restored image are to the original, and it is defined as:

$$\mathrm{MAE} = \frac{1}{b \times x} \sum_{p=1}^{b} \sum_{r=1}^{x} |t(p,r) - s(p,r)| \quad (2)$$

Where t (p,r) and s (p,r) are the pixel values of restored and original images respectively at the location (p,r).The minimum value of MAE reflects the better visual [9].

3) Peak Signal to Noise Ratio(PSNR)

$$RMSE = \sqrt{\frac{\sum [s(p,r) - t(p,r)]^2}{vz}} \quad (3)$$

$$PSNR = 20 \log_{10}\left(\frac{255}{RMSE}\right) \quad (4)$$

Where $s(p,r)$is pixel value of original CT image, $t(p,r)$ is pixel value of enhanced CT image and v and z are the total number of pixels in the horizontal and vertical dimensions of the image [20].

4) Image Enhancement Factor (IEF)

Is a measure of Image quality, and is defined as:

$$\mathrm{IEF} = \frac{\sum_p \sum_r [t(p,r) - s(p,r)]^2}{\sum_p \sum_r [t(p,r) - s(p,r)]^2} \quad (5)$$

Where $t(p,r)$ is the pixel value of corrupted image. The higher value of IEF reflects the enhanced image visualization, and better restoration performance [20].

5) Correlation Ratio (CORR)

Correlation Ratio measures the degree in which two images vary together or taking similar values from 0.0 to 1 .0 and it is defined as:

$$\mathrm{CORR} = \frac{\sum_d (s_d - s_m)(t_d - t_m)}{\sqrt{\sum_d (s_d - s_m)^2 (t_d - t_m)^2}} \quad (6)$$

Where s_d describe the intensity of the d^{th} pixel in the original image, t_d indicate to the intensity of the d^{th} pixel in the processed image, s_m describe the mean intensity value of the original image, and t_m represent the mean intensity value of the processed image. The value of CORR which gets close to 1.0 reflects the better image visualization [9].

6) Canny Edge Detection

Edges define the boundaries between regions in an image, which useful for image segmentation and object recognition [21] [22]. Canny algorithm implements a Gaussian filter for smoothing, then applying the Sobel filter to estimate the gradient in each point is then calculate the magnitude of the gradient Finally, a threshold is applied to prune the edges with small dimensions [17].

7) Morphology Operation

Mathematical morphology interacts as nonlinear function used to segment useful information and description of the object such as shape, borders, and skeletons. In a morphological combined functions (opening and erosion) it removes small objects and the subsequent dilation attempts to restore the shape of objects that remain [9]. The syntax to implement the algorithm in MATLAB (Bwareaopen) used removes the connected components (objects) that have size less than the pre-selected operator value [23].

II. METHDOLOGY

In this paper, CT images denoising method experiments were performed on the computer with Intel® Core™ i7-7700HQ CPU at 2.8 GHz, 16GB RAM, Windows 10 Home 64. Implementation of proposed logarithm was done using MATLAB (R2014a) software.

A. *Implementaion*

The steps of the proposed algorithm presented in Fig.1 described as below:

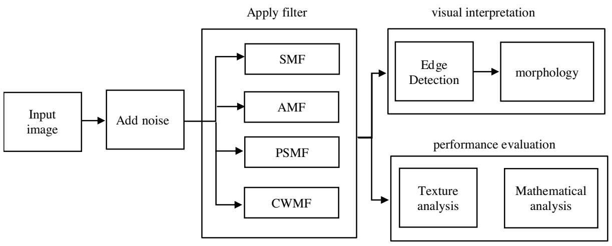


Fig. 1. Presents the block diagram of method used in denoising and performance evaluation

Step1: The Atlas web-based liver CT images of size of 256x256 were acquired.
Step2: Experiments are performed at various noise levels extend from 10% to 90%.
Step 3: four types of filters were applied (SMF, AMF, PSMF and CWMF) with kernel size of 7x7 to expel the noise.
Step 4: Evaluate the performances of filters in denoising process using visual inspection and numerical performance evaluation. Visual interpretation appraises the noise cancellation behavior and evaluates the performance of these filters in edge preserving of the regions of interest. Canny edge detection was implemented combined by morphological to eliminate small unwanted extracted details using ‘bwareaopen’ function using ‘disk size’ to remove objects of size less than 70 connected pixel.

III. RESULT AND DISCUSION

50% density of impulse noise is added to CT images, after that the logarithms of median based filters are applied to the image and result showing in Fig.2 illustrates the used noisy image and restored images.

1) Visual Interpretation

To evaluate the characteristics of edge-preserving of median-based filters for selectively eliminating noise without affecting the resolution of CT images apply standard enhancement of edge to translate the edge in final results presented in Fig.3.
After applying the filter to remove the 50% density noise, canny filter and morphology process (bwareaopen) with disk size equal 70, applied for edge detection and to remove any small connected component.

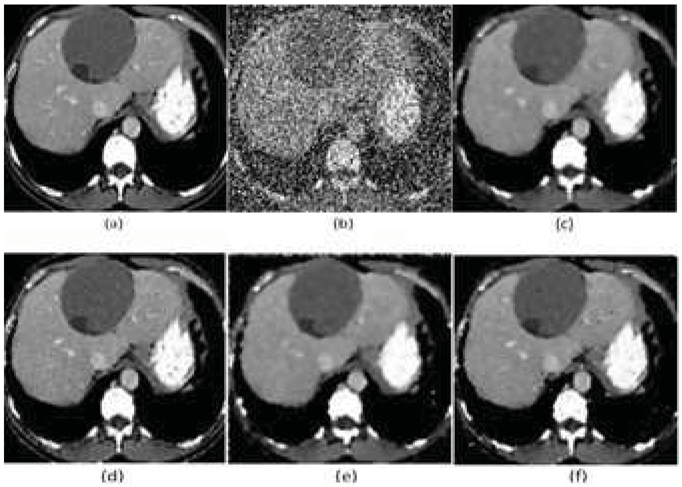


Fig.2. (a) original image. (b) 50% noisy image denoised by: (c) Standard median filter. (d) Adaptive median filter. (c) Center weight median filter. (e) Progressive switched median filter.

2) Performance Evaluation

In order to measure the quality of the image after filtering process and analytical comparisons of performance of algorithm for median based filters the following parameters are used.

a) Texture Analysis (Stastistical)

Couple of texture parameters used to analyze the spatial distribution of gray values, to compare those features of images before and after filtering to assess the performance. In this paper, use six equations were executed (mean, standard deviation, smoothness, third moment, uniformity and entropy) from CT liver image. The measurement was presented, table 1 present the performance.

Table 1tubular data of texture analysis illustrate the values of texture for the original image, noisy image and texture values of the texture after denoising using (SMF, AMF, CWMF and PSMF).

	mean	Standard deviation	smoothness	Third moment	uniformity	entropy
Original image	494.7085	452.3951	0.4824	19.3305	0.6379	35.4908
Noisy density (50%)	630.824	643.3506	0.9015	42.4472	1.4434	23.7885
SMF	484.9774	446.8473	0.4716	18.9427	0.6525	34.5484
AMF	498.98	453.2623	0.4841	19.434	0.5823	36.0939
CWMF	489.6575	451.0683	0.4798	20.2643	0.6374	34.6844
PSMF	481.6169	453.8675	0.4853	21.388	0.7712	33.4803

b) Mathematical Analysis

To evaluate the performance of the kernels for elimination of impulse noise and assess their comparative execution (performance), diverse noise densities starting from 10% up to 90% were integrated and for de-noising, the noisy images the four median-based filters were utilized as SMF, AMF, CWMF, and PSMF.

The performance of all the four filters was analyzed and discussed. We select power signal to noise ratio, mean square error, correlation ratio, and image enhancement factor to evaluating the enhancement of CT images. To validate the proposed methodology, a CT liver image 256x256 jpg was utilized in simulation in various levels of noise densities. The comparison was done in terms of PSNR, MSE, CORR, and IEF where the result illustrated in Figs.4, Fig.5, Fig6 and Fig, 7 respectively.

Median based filters such as the SMF, AMF, CWMF, and PSMF function for eliminating only noise elements in regions with high noise elements in order to improve the density resolution.

An evaluation for edge-preserving using the mentioned filter was conducted , in the original image, a three pilot objects 'regions of interest' was assigned and illustrated in Fig.3, cyst, stomach and vertebra, and behavior of median filtering to obtain uniform boundary of each object.

After applying the filter and by visual comparison we can clearly see their ability to maintain the edge of these objects.

In final images of CWMF and SMF a part of detailed information lost after denoising process and edge image is not quite well while the PSMF performed fairly well in maintaining the edges of the areas concerned but there are additional details in the detection of the edges and this is due not to completely remove the noise, whereas the result of AMF gives better edge appearance for three objects by making the details visually richer and complete, there are no false edge and gets an ideal effect.

In texture (statistical) analysis from the table 1 illustrate the values of texture for the original image, noisy image and texture value of the images after denoising using (SMF, AMF, CWMF, and PSMF).

Compare the image texture values before and after applying the filters, to see which of these filters gives a close result to the original image before adding the salt and pepper noise with 50% pdf density. It is interesting to note that in all six textures the result of the Adaptive median filter has a superior performance over the rest of the filters when we compare the resulting values of the image filtered through it with the original image.

The results of the mathematical analysis are showing in Fig.4, Fig.5 and Fig.6 It can illustrate that (SMF, CWMF, and PSMF) filters provide a low performance when they are contrasted with (AMF) filter at various noise densities.

In noise density ranging from 10% to 50% the results of (SMF, CWMF and PSMF) give lower (PSNR, CORR, and IEF) respectively ,if their performance compared with (AMF), it could be notice that the performance of the (AMF) is better than others at these levels of noise density PSNR (10% - 50%). In contrast the (SMF) is superior to other filters at PSNR (60% - 90%) and MSE (10% - 90%) noise densities, In Fig.7 there is a clear that (AMF) tend to perform better than other filters at IEF at all densities.

IV. CONCLUSION

In this investigation, the aim was to assess the application of the different median based filter on the CT image and evaluate their performance.

This paper discusses the behavior of median based filter (SMF, AMF, CWMF, and PSMF) in denoising process of salt and pepper noise and edge maintain, the experiments have been conducted on CT image evaluate various algorithms. And finally, it compares simulation results.

The experimental result of comparative analysis both visual and quantitative outcome denote that the Adaptive Median Filter (AMF) performs significantly better than other filters.

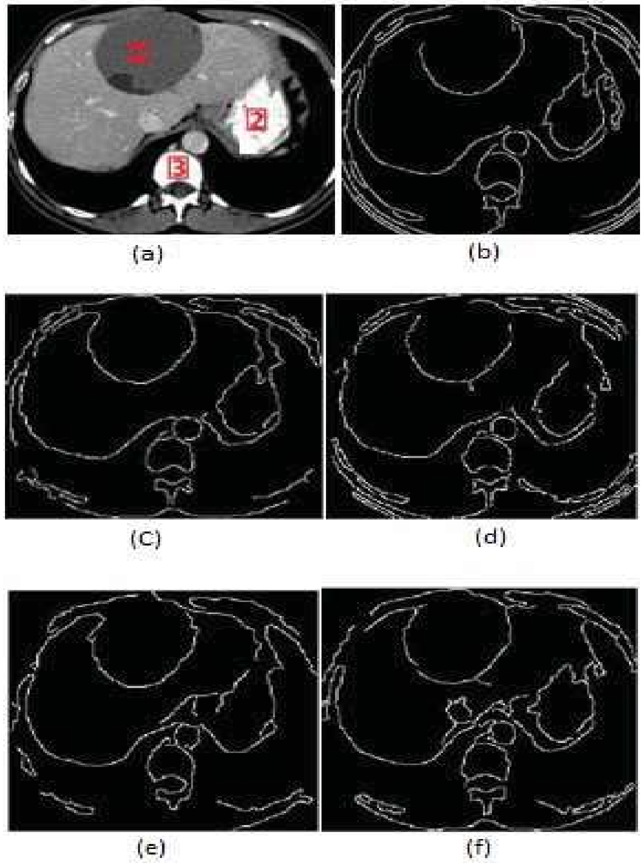
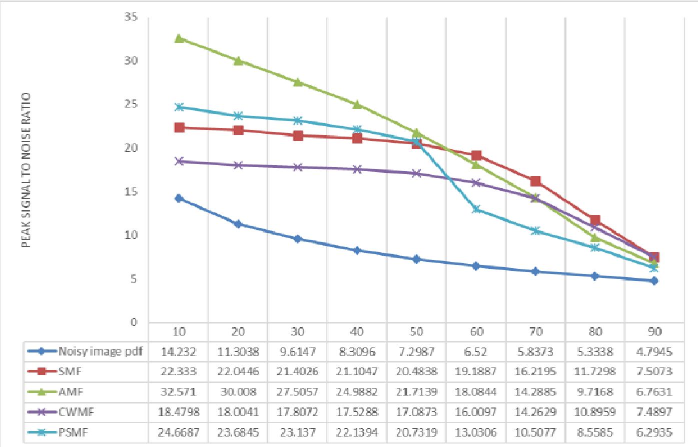
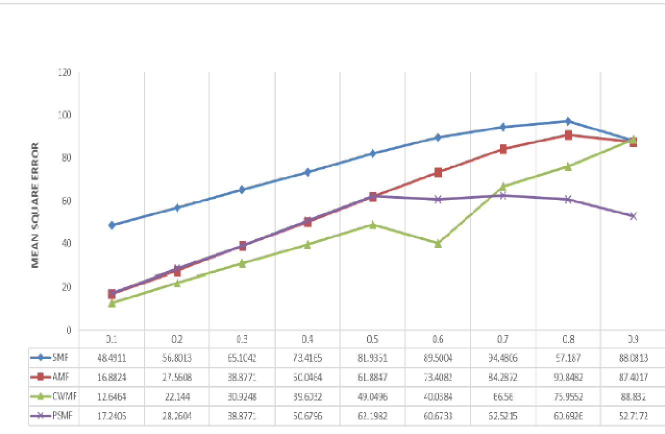


Fig. 2.Comparison of performance of different filters in edge preservation. (a) Original image with three regions of interest: (1) Cyst, (2) stomach, (3) Vertebra (spinal cord). (b) Morphology of original image. (c) Result after denoising by AMF, (d) result after denoising by CWMF and (f) result after denoising by PSMF. Images result from applying canny edge detection filter and open area morphology technique.



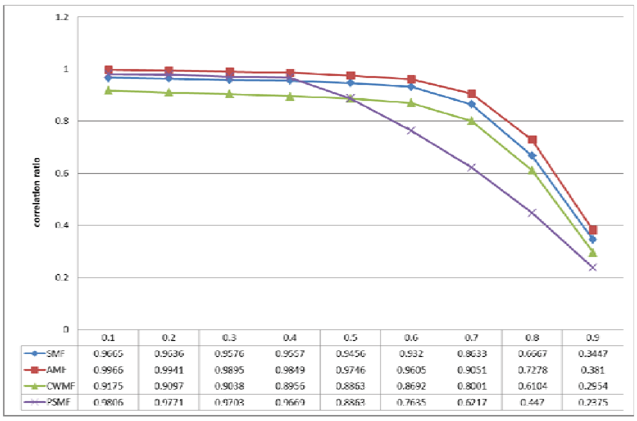
	10	20	30	40	50	60	70	80	90
Noisy image pdf	14.232	11.3038	9.6147	8.3096	7.2987	6.52	5.8373	5.3338	4.7945
SMF	22.333	22.0446	21.4026	21.1047	20.4838	19.1887	16.2195	11.7298	7.5073
AMF	32.571	30.008	27.5057	24.9882	21.7139	18.0844	14.2885	9.7168	6.7631
CWMF	18.4798	18.0041	17.8072	17.5288	17.0873	16.0097	14.2629	10.8959	7.4897
PSMF	24.6687	23.6845	23.137	22.1394	20.7319	13.0306	10.5077	8.5585	6.2935

Fig.4 Comparison graphs and outcome for PSNR for CT liver image at different noise densities.



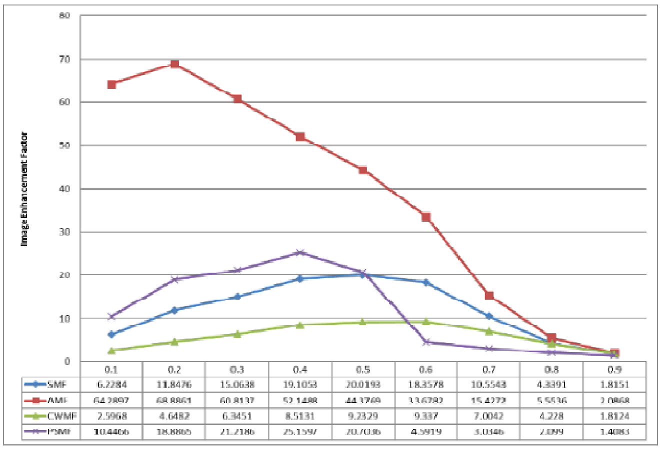
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
SMF	48.4911	56.8013	65.1042	73.4165	81.9351	89.5004	94.4806	97.187	88.0813
AMF	16.8824	27.5608	38.8771	50.0464	61.8847	73.4082	84.2872	90.8482	87.4017
CWMF	12.6464	22.144	30.9248	39.6032	49.0496	40.0384	66.56	75.9552	88.832
PSMF	17.2405	28.2604	38.8771	50.6796	62.1982	60.6733	62.5215	60.6926	52.7172

Fig.5Comparison graphs and outcome for MSE for CT liver image at different noise densities.



	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
SMF	0.9665	0.9636	0.9576	0.9557	0.9456	0.932	0.8633	0.6667	0.3447
AMF	0.9966	0.9941	0.9895	0.9849	0.9746	0.9605	0.9051	0.7278	0.381
CWMF	0.9175	0.9097	0.9038	0.8956	0.8863	0.8692	0.8001	0.6104	0.2954
PSMF	0.9806	0.9771	0.9703	0.9669	0.8863	0.7635	0.6217	0.447	0.2375

Fig.6 Comparison graphs and outcome for CORR for CT liver image at different noise densities.



	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
SMF	6.2284	11.8476	15.0638	19.1053	20.0193	18.3578	10.5543	4.3391	1.8151
AMF	64.2897	68.8861	60.8137	52.1488	44.3769	33.6782	15.4272	5.5536	2.0868
CWMF	2.5968	4.6482	6.3451	8.5131	9.2329	9.337	7.0042	4.228	1.8124
PSMF	10.4466	18.8865	21.2186	25.1597	20.7036	4.5919	3.0346	2.099	1.4083

Fig.7 Comparison graphs and outcome for IEF for CT liver image at different noise densities.

REFERENCES

[1] S. Arastehfar, A. A. Pouyan,and A. Jalalian, "An enhanced median filter for removing noise from MR images," Journal of AI and Data Mining, Vol.1, No.1, 13-17, 2013.

[2] Anisha Bhatia, " Salt-and-pepper noise elimination in medical image based on median filter method," International Journal of Electrical, Electronics and Data Communication, ISSN: 2320-2084, Vol. 1, Issue- 6 Aug-2013.

[3] C. Nagaraju, S. S. ParthaSarathy, "Analysis and estimation of noise in embedded medical images," I.J. Image, Graphics and Signal Processing, 3, 45-50, February 2015.

[4] Pawan Patidar, Manoj Gupta, Sumit Srivastava, and Ashok Kumar Nagawat, "Image de-noising by various filters for different noise," International Journal of Computer Applications 0975–8887, Vol. 9– No.4, November 2010.

[5] V. Labunetsa, E. Osthaimerb, "Systematic approach to nonlinear filtering associated with aggregation operators part 2. fréchet mimo-filters," ScienceDirect, Procedia Engineering 201 (2017) 385–397, April 2017.

[6] Ognjen Magud, Eva Tuba And Nebojsa Bacanin, "Medical ultrasound image speckle noise reduction by adaptive median filter," wseas transactions on biology and biomedicine, E-ISSN: 2224-2902, Vol. 14, 2017.

[7] Amanpre Kaur, Rahul Malhotra and Ravneet Kaur, "Performance evaluation of non-iterative adaptive median filter," IEEE International Advance Computing Conference (IACC) 978-1-4799-8047, 2015

[8] James Church, Yixin Chen, and Stephen Rice, "A spatial median filter for noise removal in digital images" 30 August 2016

[9] R. C. Gonzalez and R. E.Woods, "Digital image processing," Nueva Jersey, 2008

[10] Abdulaziz Saleh Yeslem Bin-Habtoor, Salem Saleh Al-amri "Removal speckle noise from medical image using image processing techniques," (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 7 (1), 375-377, 2017

[11] Deepika, Yogesh Kumar, "Enhancement in progressive switching median filter for denoising noise," IJETSR, ISSN 2394 – 3386, Volume 4, Issue 8, August 2017.

[12] Department of radiology, washington university, "the liver imaging atlas,"[online]. Available:

https://liveratlas.org/ .[accessed: Friday, March 09, 2018, 11:33 pm].

[13] J.Harikiran, B.Saichandana, and B.Divakar, "Impulse noise removal in digital images," International Journal of Computer Applications 0975–8887,Vol. 10– No.8, November 2010.

[14] Hanafy M. Ali, "MRI medical image denoising by fundamental filters," SCIREA Journal of Computer, Vol. 2, Issue 1, February 2017.

[15] "Echinococcosis fact sheet n°377". World Health Organization. March 2014. Archived from the original on 21 February 2014. Retrieved 19 March 2014.

[16] J. W. Tukey, "Methods for smoothing data," Nonlinear (Nonsuperposable) Conference Record EASCON, p. 673. 1974.

[17] Thomas B. Moeslund. Image and Video Processing. August 2008.

[18] R. Marudhachalam and Gnanambal Ilango,. "Center weighted hybrid filtering techniques for denoising of medical images," World Congress on Engineering and Technology, 542-545, 2011

[19] Jeba Derwin, Tamilselvi "Boundary based progressive switching median filter for the removal of impulse noise in highly corrupted images," International Journal of Engineering Science Invention Research & Development; Vol. II Issue V November 2015.

[20] Hassan M. ElKamchouchi, Ahmed E. Khalil, Samy H. Darwish "Performance of non-linear cascaded filtering algorithm for reoval of impulse noise in digital images" IJSSST , vol. 1, 2000.

[21] Ehsan Nadernejad, "Edge detection techniques: evaluations and comparisions" Applied Mathematical Sciences, 1507–1520, Vol. 2, no. 31, 2008.

[22] John Canny, "A computational approach to edge detection. Pattern Analysis and Machine Intelligence," IEEE Transactions on, PAMI-8(6):679–698, Nov. 1986.

[23] Zhao Fang, Ma Yulei, Zhang Junpeng "Medical image processing based on mathematical morphology," the 2nd international conference on computer application and system modeling, 2012.