Performance Analysis of Gaussian, Median, Mean & Weiner Filters on Biomedical Image De-noising

Subrato Bharati[1*], Prajoy Podder[2]

[1,2] Institute of ICT, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

*Corresponding Author: Email: subratobharati1@gmail.com; ORCID: 0000-0001-8849-4313

Abstract. Noise reduction in medical images is a perplexing undertaking for the researchers in digital image processing. Noise generates maximum critical disturbances as well as touches the medical images quality, ultrasound images in the field of biomedical imaging. The image is normally considered as gathering of data and existence of noises degradation the image quality. It ought to be vital to reestablish the original image noises for accomplishing maximum data from images. Medical images are debased through noise through its transmission and procurement. Image with noise reduce the image contrast and resolution, thereby decreasing the diagnostic values of the medical image. This paper mainly focuses on Gaussian noise, Pepper noise, Uniform noise, Salt and Speckle noise. Different filtering techniques can be adapted for noise declining to improve the visual quality as well as reorganization of images. Here four types of noises have been undertaken and applied on medical images. Besides numerous filtering methods like Gaussian, median, mean and Weiner applied for noise reduction as well as estimate the performance of filter through the parameters like mean square error (MSE), peak signal to noise ratio (PSNR), Average difference value (AD) and Maximum difference value (MD) to diminish the noises without corrupting the medical image data.

Keywords: Gaussian noise, Speckle Noise, Mean square error(MSE), DE noising filters, Maximum difference value (MD), Peak signal to noise ratio(PSNR)

1 Introduction

Noise illustrate undesirable data, which break down the picture quality. It is characterized as a procedure which influences the obtained picture. Noise is introduced into pictures ordinarily while exchanging and gaining them. An Image noise causes irregular variety of contrasts in the images. Images are influenced by different sorts of commotion, for example, Gaussian noise generate via regular sources for example particles thermal vibration as well as separate nature of radiation of warm object [1], Exponential noise, Speckle noise is an intricate phenomenon, which corrupts picture value with back scattered wave presence which begins from numerous microscopic dispersed reflections that going over interior organs besides creates it more troublesome for the spectator to distinguish fine element of the image in investigative checkups [2], Salt-and-Pepper noise [3] likewise alluded as information drop noise. The picture is not completely ruined by salt & pepper noise rather than some pixel qualities are altered through noise. In spite of noisy image, there is a plausibility of some neighbor's un-change. In case of data transmission this noise is found. Image pixel qualities are supplanted by defiled values of pixel either greatest "or" least pixel value specifically, 0 "otherwise" 255 individually. if transmission bits are 8. Poisson noise [4] and Periodic noise is produced from gadgets obstructions, particularly in power signal during image procurement. This noise has uncommon qualities corresponding spatially reliant besides sinusoidal in environment at products of a particular frequency. Periodic noise can be advantageously evacuated by utilizing a notch filter or narrow band reject filter [5], Uniform noise presence is essential in amplitude quantization procedure. It introduces, because of analog data changed over into digital data. In this noise model, the signal to noise ratio (SNR) is restricted by the least and highest pixel esteem [6]. The principle sort of noise which is happening during the picture procurement is called Gaussian noise. Then again salt and pepper noise is for the most part presented while transmitting image information over an unsecure correspondence filter. Along these lines, it is required to dispose of the noise from the picture to get exact information and degenerate the visual nature of the pictures. There are different kind of filters use for picture noise decrease. For example, Geometric mean filter, Harmonic mean filter, Median filter, Weiner filter, Midpoint filter, Max & min filter, Alpha-trimmed mean filter, Adaptive filter, Band pass filter, Notch filter, Band reject filter and so on. With a specific end goal to expel noise and enhance visual quality in this structure four dissimilar filter are utilized. Besides filter output data are evaluated utilizing five filters superiority measures parameters. Histograms of these loud pictures are additionally discovered. The state of the histogram of the images has been demonstrated the kind of the noise present in the images. Fig.1 demonstrates the image degradation as well as restoration process where the input image is f(x,y) and g(x,y)is the noisy image. Image obtained after the restoration block is called the filtered image [7].

The paper is oriented in this fashion; the outline of the working process describes in division II. Types of image noise describes in division III, under this division Gaussian, speckle, salt and pepper and uniform noises are illustrated. Division IV designates the de noising filters like mean, Gaussian, median and Weiner filters. Besides experimental results represent in division V and division VI accomplishes this paper.

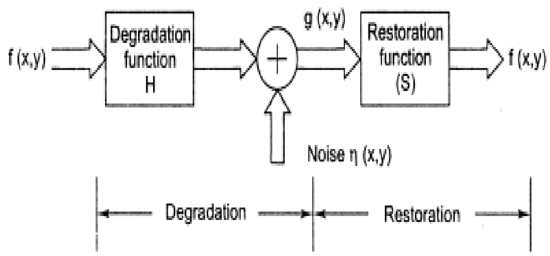

Fig. 1. Image degradation and restoration model

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2 Overview of the working process

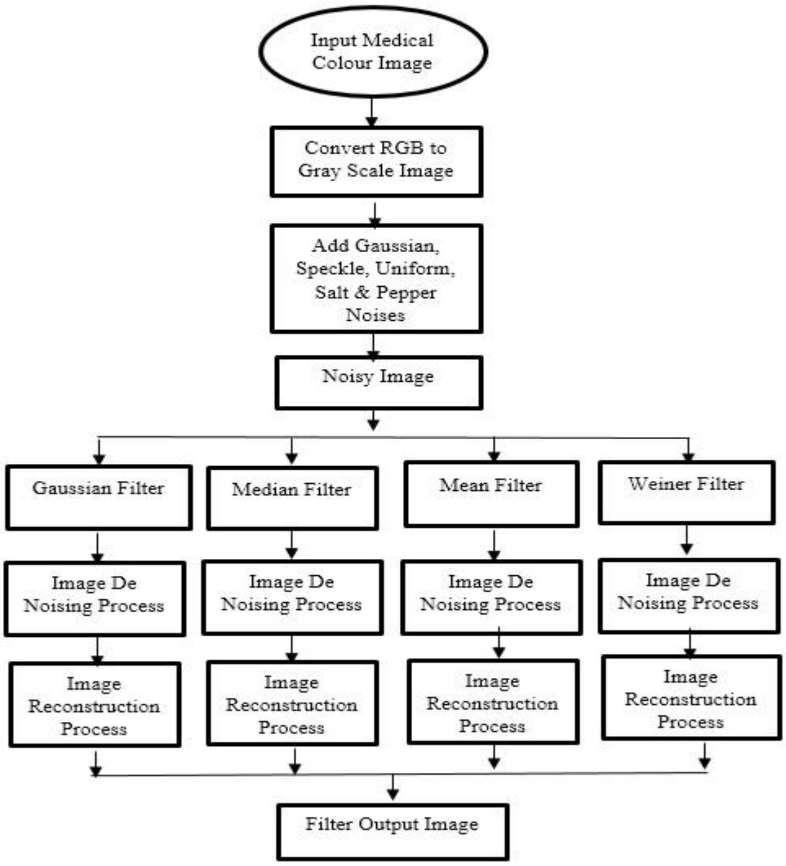

Fig. 2. Flowchart of working procedure

3 Types of Image Noise

3.1 Gaussian Noise

Gaussian noise is likewise called enhancer noise or random variation impulsive noise. Gaussian noise is created because of (an) electronic circuit noise, (b) sensor noise because of high temperature, (c) sensor noise because of poor brightening [8][9]. It is a sort of measurable noise where the sufficiency of the noise takes after Gaussian dissemination [10]. Gaussian noise emerges as probability density function of the regular distribution. The PDF of Gaussian noise,

$$P(z) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-(z-\mu)^2}{2\sigma^2}} \qquad (1)$$

3.2 Speckle Noise

In [9], [10] Speckle noise is one kind of granular noise and the picture quality has been degraded by this speckle noise. The images which are acquired from medical are spoiled by the speckle noise. Generally, speckle noise expands the mean gray near of a native area and causing difficulties in medical because of coherent processing of backscattered signal.

3.3 Uniform Noise

Uniform or Quantization noise is created by quantizing the pixels of a detected picture to various discrete levels. In spite of the fact that it can be flagged subordinate however it will be flagged free if the sources of other noise are sufficiently enormous to source dithering [8].

The PDF of uniform noise is given by,

$$P(z) = \begin{cases} \frac{1}{b-a}, if a \leq z \leq b \\ 0, otherwise \end{cases} \quad (2)$$

Mean value is specified by,

$$\mu = \frac{a+b}{2} \quad (3)$$

Variance is given by,

$$\sigma^2 = \frac{(b-a)^2}{12} \quad (4)$$

3.4 Salt and Pepper Noise

Salt & Pepper noise is called as Impulse noise. It can likewise be named as spike or fat–tailed distributed noise [11]. The salt and pepper noise is brought about by sudden and sharp disorder in the image signal. It is appearance as arbitrarily scattered dark or white (or together) pixels above the image. It is digitized as great qualities in the image. Impulse noise contained image has dark pixels in the bright region and splendid pixels in dull areas [8]. The PDF of (bipolar) impulse noise can be communicated as [8].

$$p(x) = \begin{Bmatrix} P_a, for\ x = a; \\ P_b, for\ x = b; \\ 0, otherwise \end{Bmatrix} \quad (5)$$

If b>a, gray level b will perform as a light dot in the image. On the contrary, level a will act similar to a dark dot. The impulse noise is called uni-polar when P_a or P_b is zero.

4 Image De-Noise Filters

Image de-noising filters have an extensive variety of uses. For example, medical image investigation, signal (video, sound, voice) examination, information removal, radio space science, etc. Every application has its exceptional necessities. For instance, noise evacuation in medicinal signs requires particular consideration since information taken from the medical signal (ECG, EEG and so on.) is exceptionally touchy. Noise free images are basically required for line, point and edge discovery. In the field of image preparing smoothing and honing are two general filters for accessible.

High frequency parts can be contained in the images. Smoothing filters can assume an imperative part to suppress those high frequencies. Then again, sharping filters are utilized to smooth image low frequency, i.e. improving or recognizing picture edges. Image rebuilding and upgrade methodologies can be characterized into spatial domain and frequency domain classifications. This arrangement is typically in light of changing Fourier transformation of an image. Noise evacuation is perplexing in the frequency domain when contrasted with the spatial domain. The spatial domain noise expulsion involves fewer meting out time. Noise removal algorithms ought to give a tasteful measure of noise evacuation furthermore safeguard the edges. For fulfill expressed conditions there are two sorts of filters: linear and non-linear with their noteworthy favorable circumstances and disservices. The linear filters have the benefit of speedier planning and the shortcoming of not sparing edges. A fact in non-linear filters has the upside of securing edges and the downside of slower preparing [12]. In this work, four kind of filters have been talked about underneath which will be utilized further to expel the noise info from the main image.

4.1 Median Filter

Order-statistics filter also known as Median filter, which exchanges the estimation of a pixel by the middle of the gray levels in the region of that pixel. The median is a rank command statistic and in a intelligence the main stream of the pixel values included determines the result [13]. The expression of Median filter,

$$f'(x,y) = \underset{(s,t)\in S_{xy}}{median}\{g(s,t)\} \quad (6)$$

The first estimation of the pixel is incorporated into the calculation of the median. Median filters are extremely standard for assured sorts of arbitrary noise. They give astonishing noise diminish capacities, with stunningly less clouding than a linear smoothing filter of comparative size [14].

The median is figured by first sorting all the pixel values from the window in numerical order. A while later supplanting the pixel being considered with the inside (middle) pixel value. Median filters are viable for the bipolar and unipolar impulse noise. Median filters are mainly reasonable within the sight of both unipolar and bipolar impulse noise.

4.2 Gaussian Filter

Gaussian filter is a linear smoothing filter, where the weights chosen for the smoothing purpose according to the outline of the function of Gaussian. Gaussian filter in the nonstop space and can be defined by the resulting equation,

$$h(m,n) = \left(\frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{m^2}{2\sigma^2}}\right) \times \left(\frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{n^2}{2\sigma^2}}\right) \quad (7)$$

One-dimensional Gaussian filter has an impulse response,

$$g(x) = \sqrt{\frac{a}{\pi}} e^{-ax^2} \quad (8)$$

This equation can also be uttered with the standard deviation as parameter [8]

$$g(x) = \frac{1}{\sqrt{2\pi}.\sigma} e^{-\frac{x^2}{2\sigma^2}} \quad (9)$$

Where, the standard deviations are mentioned in their physical units, e.g. time and frequency in seconds and Hertz [15] [16].

4.3 Mean Filter

Mean filtering simplest way to decrease the amount of intensity deviation between one and next pixel for smoothing image [10]. Arithmetic mean filter can be expressed by [17].

$$f'(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t) \quad (10)$$

At this time, g is the ruined image, r and c are the row and column co-ordinates correspondingly within a window size of m×n besides the filtered image is $\hat{f}(x,y)$. However geometric mean filter is a variation of the arithmetic mean filter, which calculated appearance can be known as follows,

$$f'(x,y) = \left[\prod_{(r,c)\in W} g(r,c)\right]^{1/mn} \quad (11)$$

4.4 Weiner Filter

The Weiner filter is a standout amongst the most fundamental methodologies for noise diminishment and it can be defined in either the frequency or time domain. Time domain Weiner filter is gotten by minimizing the MSE between the image of interest and its assessment [18]. The wiener filter is ideal in minimum mean square error sense for recuperating noise image. The detected image g(x,y) is thought to come about because of the entirety of the stationary noise n(x,y) and original image f(x,y).

$$g(x, y) = f(x, y) + n(x, y) \quad (12)$$

Where noise is spectrally white with zero mean and variance σ^2. The transfer function of the Weiner filter is,

$$H(u, v) = \frac{P_f(u,v)}{P_f(u,v)+\sigma^2} \quad (13)$$

For image retrieval noise adaptive Weiner filtering is expressed as [14],

$$f'(x,y) = m_f(x,y) + \frac{\sigma_f^2(x,y)}{\sigma_f^2(x,y)+\sigma_n^2(x,y)}\left(g(x,y) - m_f(x,y)\right) \quad (14) \quad (14)$$

5 Experimental Results

Matrix laboratory software (MATLAB) has been used to analysis the performances of noise elimination filters on four different types of noise.

Fig. (3,4,5,6,7) refer to the effect of filtering consecutively for removing the Gaussian noise, speckle noise, unifrom noise, salt & pepper noise from medical images. Where, Fig. (3(a), 4(a) (h), 5(a), 6(a), 7(a)) signifies the orginal images.

Fig. (3(b), 4(b) (g), 5(b), 6(b), 7(b)) represents sequentially gaussian noise, speckle noise, unifrom noise, Salt and Pepper noise images.

Fig. (3(c), 4(c) (i), 5(c), 6(c), 7(c)) represents median filter for removing the Gaussian noise, speckle noise, unifrom noise, salt & pepper noise from medical images.

Fig. (3(d,e,f), 4(d,e,f) (j,k,l), 5(d,e,f), 6(d,e,f), 7(d,e,f)) represents consecutively gaussian, mean, winer filters for removing the gaussian noise, speckle noise, unifrom noise, salt & pepper noise from medical images.

Fig. (8, 9, 10, 11) evaluate the performances analysis of Gaussian, Median, Mean and Weiner filters performance through MSE, PSNR, AD as well as MD.

a 

b 

c 

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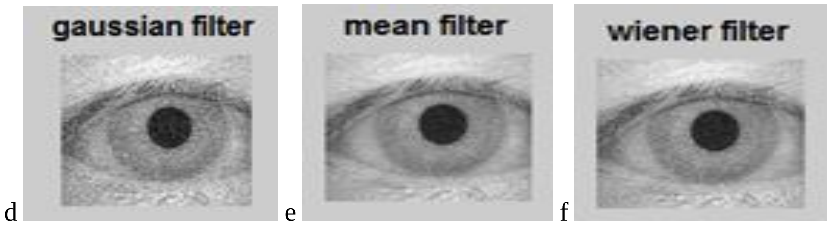

Fig. 3. Result of filtering for removing Gaussian noise

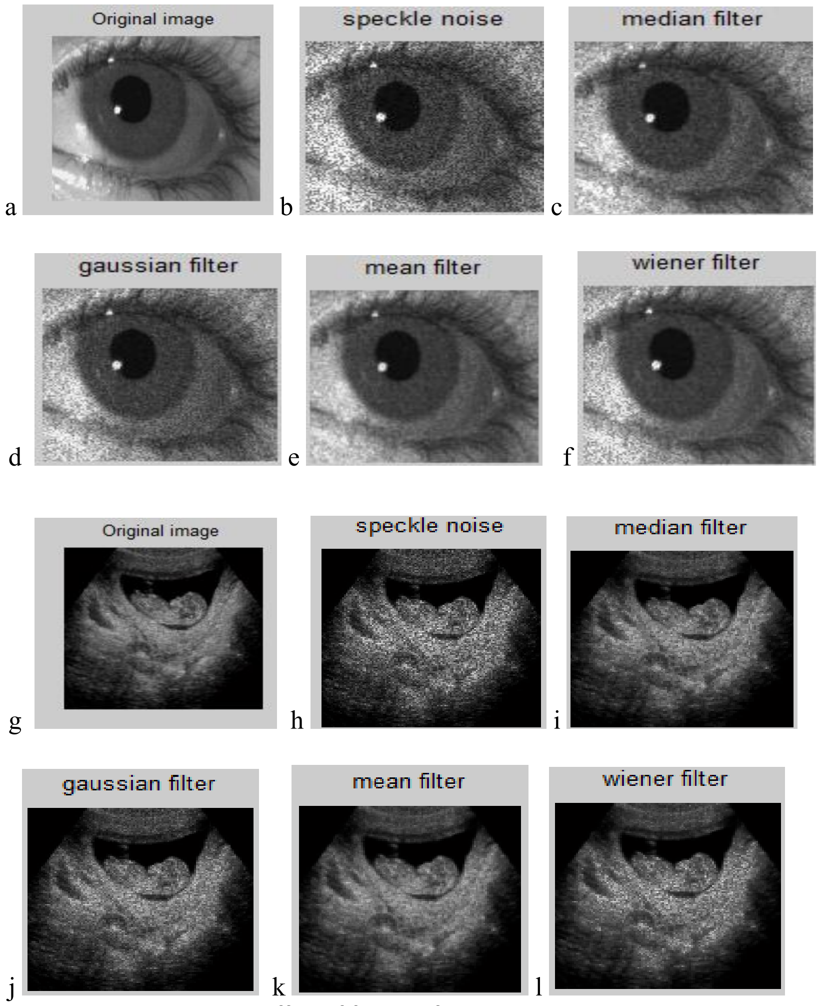

Fig. 4. Effect of filtering for removing Speckle noise

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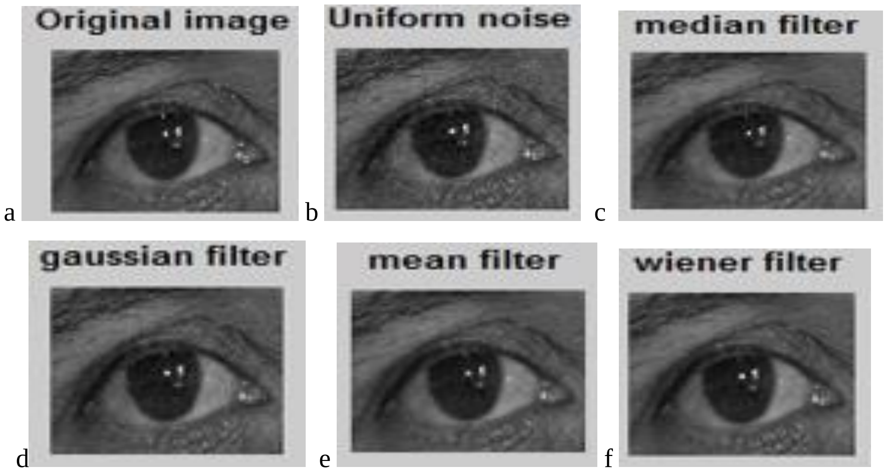

Fig. 5. Result of filtering for removing Uniform noise

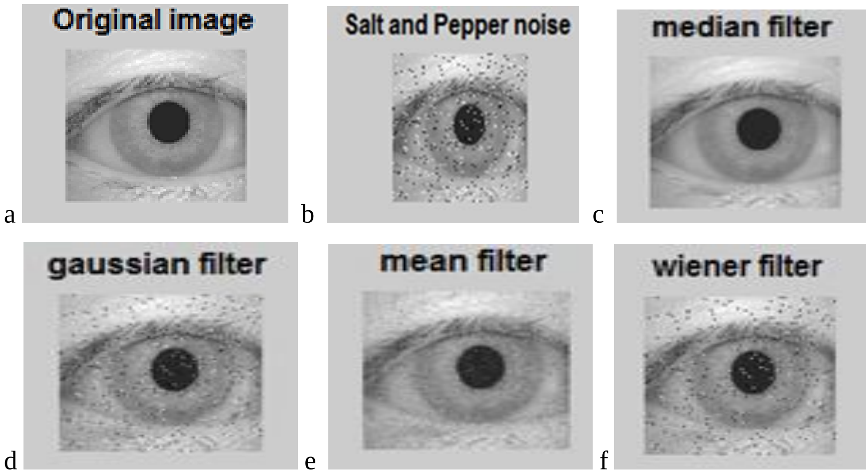

Fig. 6. Result of filtering for eliminating Salt and Pepper noise

Fig. 7. Result of filtering for eliminating Speckle noise from Ultrasound image

5.1 Mean Square Error (MSE)

Mean square error can be calculated by the following equation,

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}[g(x,y) - f(x,y)]^2 \qquad (8)$$

Where, MxN is the total number of pixels, g(x,y) is corrupted image and f (x,y) is filtered image. The lowest value of mean square error represents the best filtered image.

Table 1. Gaussian Filter Performance Analysis on Different Type Noises

Gaussian Filter	Types of noise			
	Gaussian	Speckle	Uniform	Salt & Pepper
MSE	45.46	67.82	9.74	25.77
PSNR	30.39	29.92	37.89	34.04
AD	4.40	6.10	1.61	2.89
MD	254	255	254	254

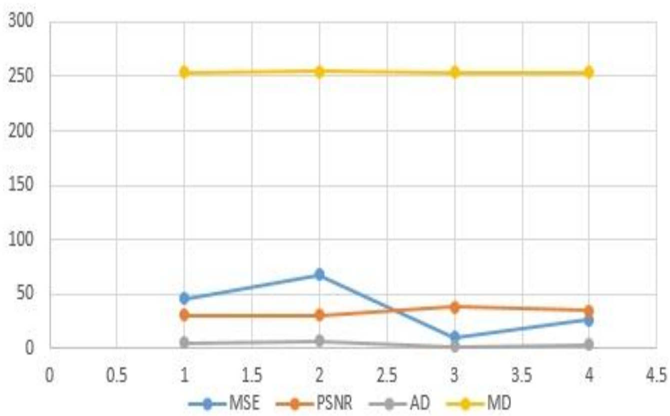

Fig. 8. Performance analysis of Gaussian filter

Table 1 and fog.8 shows that Gaussian filter is ideal for uniform noise than other noises reduction. Because of lower MSE, AD, MD as well as higher PSNR value. Besides gaussian noise reduction can be possible more by guassian filter than median, mean and weiner filters.

5.2 Peak Signal to noise ratio (PSNR)

The Peak Signal to Noise Ratio (PSNR) can be considered by the following equation,

$$PSNR = 10 \log_{10}\left[\frac{255 \times 255}{MSE}\right] \quad (9)$$

For image quality measurement, if the value of PSNR is very high for an image of a particular noise type then it is defined as a best quality image.

Table 2. Median Filter Performance Analysis on Different Type Noises

Median Filter	Types of noise			
	Gaussian	**Speckle**	**Uniform**	**Salt & Pepper**
MSE	78.14	87.29	31.37	15.80
PSNR	29.25	28.77	33.20	36.18
MAD	9.36	13.6	3.15	3.85
MD	215	195	205	225

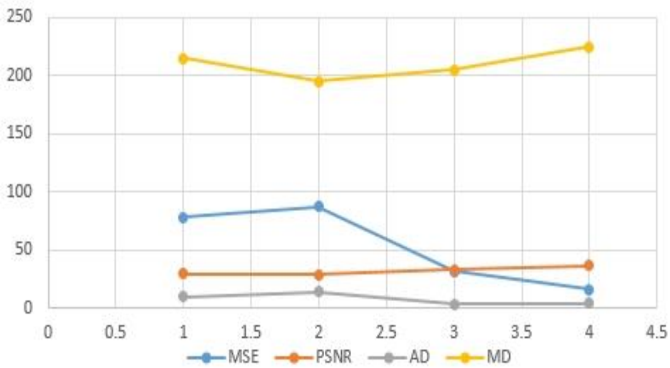

Fig. 9. Performance analysis of Median filter

In case of median filter, salt & pepper noise is appropriate for best noise reduction performances for medical images due to highest PSNR and lowest MSE value (from table II). However median filter works well for unifron noise reduction.

5.3 Average Difference value (AD)

A lower value of average difference represents a cleaner image. The average difference can be calculated by following equation,

$$AD = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} [g(x,y) - f(x,y)] \qquad (10)$$

Table 3. Mean Filter Performance Analysis on Different Type Noises

Mean Filter	Types of noise			
	Gaussian	**Speckle**	**Uniform**	**Salt & Pepper**
MSE	87.81	101.12	36.56	50.91
PSNR	28.74	28.12	32.67	31.10
AD	10.37	14.22	4.10	6.97
MD	251	255	253	252

Table 3 shows speakle noise produces higher MSE values noise reduction whereas uniform, salt & pepper noise provides smaller value of MSE in order to mean filter.

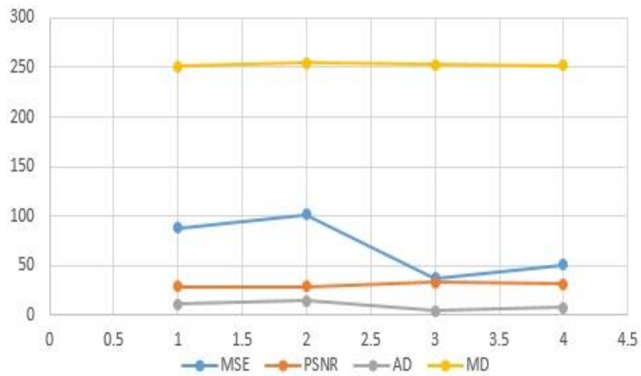

Fig. 10. Performance analysis of Mean filter

5.4 Maximum Difference (MD) value

Maximum Difference can be expressed by the following formula,

$$MD = Max\,(\,|f(x,y) - g(x,y)\,|) \qquad (11)$$

The picture quality is poor if the value of Maximum difference is large.

Table 4. Winer Filter Performance Analysis on Different Type Noises

Weiner Filter	Types of noise			
	Gaussian	**Speckle**	**Uniform**	**Salt & Pepper**
MSE	82.70	97.18	28.64	22.31

PSNR	29.14	28.30	33.59	34.67
AD	8.62	11.67	3.07	3.44
MD	251	254	253	252

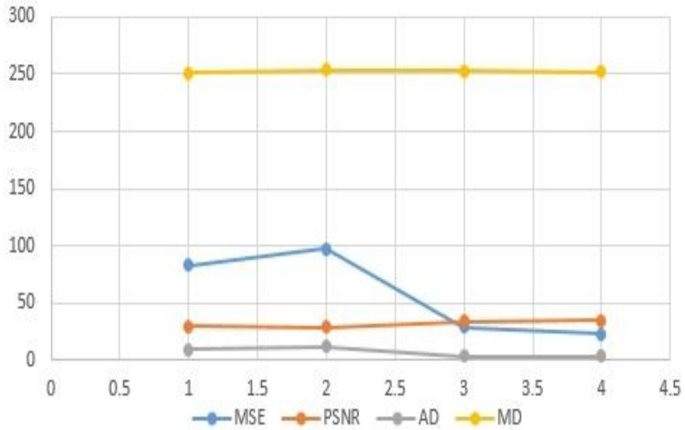

Fig. 11. Performance analysis of Winer filter

Fig. (8-11) illustrates the performances of Gaussian, median, mean and Weiner filters.

6 Conclusion

Noises are random in this environment as well as deterministic in the biomedical imaging scheme. It is difficult to remove noise present in the medical and ultrasound images, since the information about the variance of the noise may not be able to identify. This paper generally motivated on the various noise and noise suppression filters for instance Gaussian, median, mean, weiner. The working process establishes main parameters that have been pragmatic on medical images (for example Iris & Ultrasound image). Investigational opinion under MSE, PSNR, AD and MD shows the efficient filter performance at various noises. A relative study has been motivated among those filters to successfully de-noising the images. The conclusion of this study exposes that uniform noise provides relatively better performance for reduction among the other noises in terms of PSNR, MSE and visual quality. Besides Gaussian filter noise removal performances comparatively better than the median, mean and Weiner filters in case of uniform, Gaussian, speckle, salt & pepper noises.

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