Techniques for De-noising of Bio-Medical Images

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***Abstract*—**In the field of biomedical imaging, diagnosis of the patient is mainly based on images of different body parts using different types of equipment. Some of the examples of biomedical images are MRI (magnetic resonance imaging), retinal image, mammograms. These types of images involve a unique type of capturing and acquisition. In this process, images are subjected to various types of noises at various levels. Most common noises like Gaussian noise, speckle noise, salt and pepper noise, Poisson noise corrupts the important detail and makes the diagnosis mostly difficult and sometimes impossible. In order to overcome this problem different de-noising techniques like the median filter, averaging filter, wiener filter, order statistic filter de-noises the image and gives various results. In order to conclude the best filter metrics like PSNR (peak signal to noise ratio), MSE (mean square error), and SSIM (structural similarity index measure) are used. In this paper based on universal standard thresholds for metrics used graphs are drawn for each type of noise for each type of biomedical image for different variance values. Based on above thresholds we can conclude that median filter is best suited for all three types of biomedical images.

***Keywords*—**Retinal Image, MRI Image, Mammogram Image, Averaging filter, Median filter, Wiener Filter, MSE (Mean Square Error), SSIM (Structural Similarity Index Measure), PSNR (Peak Signal to Noise ratio).

I. INTRODUCTION

Biomedical image can be a retinal image or an MRI or a Mammogram. A retinal image is the fundus image of the eye. It is mainly dominated by Salt and Pepper Noise. An MRI imaging is used in diagnosing any part of the body. Typically, brain images are MRI images [5, 6, 7] and mainly dominated by Rician noise which follows the Gaussian distribution. A Mammogram is the scanned image of the breast for the determination of breast cancer. It is mainly dominated by Quantum noise. All these three are commonly prone to Gaussian, speckle, salt and pepper noise. These noises are removed by using various filters such as median filter, average filter; adaptive weighted median filter and order statistic filter [1]. The performances of these filters are measured using various performance metrics such as MSE (Mean Square Error), PSNR (Peak Signal to Noise ratio), and SSIM (Structural Similarity Index Measure).

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The main content in this paper is as described below, types of noise in section II which will be removed from defined filter and then section III describes the filters which are used for the mentioned noises and section IV describes the investigational results and discussion and finally in section V will give brief conclusion and future enhancement.

II. NOISES

The degradation in the image signal caused by external disturbance results in noise [2]. In image processing noises in any image can be gathered depends upon the conditions if it is relying on the dependent content or independent of the content. Image enhancement is the process of improving the quality of an image [4]. This is suitable for some specific applications like De-blurring or sharpening of a focused image.

- The Edges are detected
- Improving the contrast and brightness of the image.

In Process of transmission of an image from one place to another like wireless transmission or via satellite, or another cable, causes some errors. The noises presented in the images are based on pixel by pixel. So, to process these kinds of issues we have different noise types. In General, when we consider any type of restoration system, two types of noise models are present. They are the additive and multiplicative noise models [3]. The mathematical formula for the additive noise model is generally given by

$$N(x, y) = I(x, y) + J(x, y) \quad (1)$$

And the formula for multiplicative noise model is given by

$$N(x, y) = I(x, y) \times J(x, y) \quad (2)$$

Where N(x, y) is the noisy image, I(x, y) is the noise-free image and J(x, y)is the noise added to the original noise-free image. All the image de-noising techniques aim at removing the noise J(x, y) and restore the original image I(x, y) as it preserves all features of the original image.

In general, gaussian noise and salt and pepper noise comes under additive noise in which the noise will be added to each pixel and is independent of its neighbouring pixels [5]. Speckle noise comes under multiplicative noise in which the pixel intensity is varied accordingly to intensity level of the noise. Additive noises are a bit easy to remove than the multiplicative noises. Various types of noises are discussed namely, gaussian noise, quantum noise, rician noise, speckle noise, salt and pepper noise and Poisson noise [8,9].

A. Gaussian noise

Gaussian Noise is also called white noise or normal noise, which is normally distributed. It is an additive noise and the principal source of this noise is due to data acquisition. It is an additive noise; it comes from various factors. This noise only adds the signal not integrates the noise, so it is a cumulative process. That means every pixel in the noisy image is the sum of the random Gaussian distributed noise value and true pixel value. This type of noise has a Gaussian distribution. This noise is independent of each pixel and is independent of signal intensity. Gaussian Noise is the normal (bell) shaped noise, which determines the standard deviation [4]. The Probability density function P of a Gaussian Random Variable z is represented by, Gaussian Noise Distribution

$$P_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(z-\mu)^2}{2\sigma^2}} \quad (3)$$

Where, z - Grey Level Gaussian Distribution noise
μ - The Mean Value
σ – The Standard Deviation

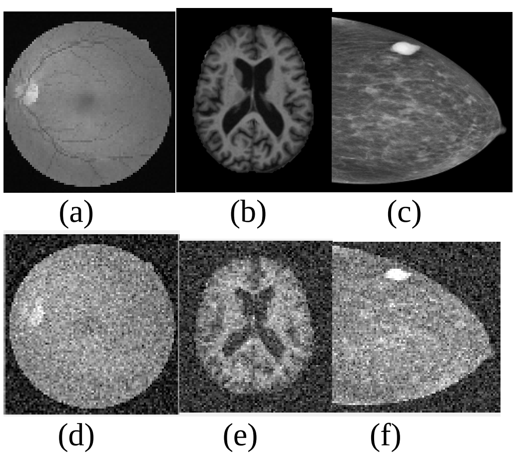

Fig. 1 (a), (b) & (c): Original images of retinal, MRI & Mammogram respectively. (d), (e) & (f) are Gaussian noise affected images.

B. *Salt& Pepper noise (Binary Noise)*

Salt and pepper noise also called as flat-tail distributed or impulse noise or shot noise or binary noise. An image which was affected by salt and pepper noise has dark pixels in bright in background and bright pixels in dark background. Salt and pepper noise is impulse type of noise, it generally occurs due to failing of camera sensors cells, during image digitization or transmission synchronization error occurs or failure in memory cells etc. It has only two possible values that is ‘a’ and ‘b’. The probability of each is typically less than 0.1. Corrupted pixels can be set alternatively to the minimum or to the maximum value, giving image a “salt and pepper” like appearance. Pixels remain unchanged for unaffected. For an 8-bit image, the value of pepper noise is 0 and for salt noise are 255. The main source of salt and pepper noise is due to the errors in ADC (Analog to Digital Converter) and due to bit errors in transmission.

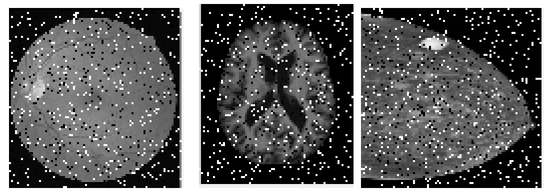

Fig. 2: Salt and Pepper Noise effected images of Retinal, MRI & Mammogram.

C. *Speckle Noise (Multiplicative Noise)*

The speckle noise is the type of multiplicative noises. In this random unwanted signal is multiplied into different relevant signal while capturing and transmission. The speckle noise is mainly recognized in radar imagery SAR (Synthetic Aperture Radar) images, medical images. The product of the mean value can be taken an exponential random variable. Speckle noise is generally defined based on medical survey is image texture. The speckle noise is represented as,

K (i,j)= x(i,j) * n(i,j)+ (i,j) (4)

Where (i, j) is the practical image, n (i, j) is the multiplicative factor and (i, j) is the additive factor of the speckle noise. Here i and j denotes the axial and neighbouring keys of an image samples. In radar applications the major problem is speckle noise. Speckle noise is mainly caused by the constructive and destructive interference of the ultrasonic waves that are passed in to the human body.

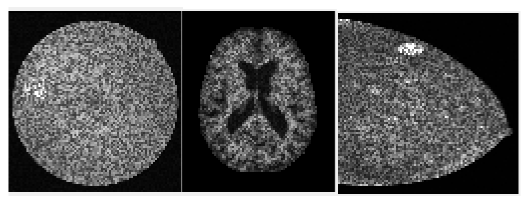

Fig. 3: Speckle noise effected images of Retinal, MRI & Mammogram.

D. *Poisson Noise (quantum noise)*

The photon noise is also called shot noise. It is based on Poisson distribution, which generally totally varies from Gaussian noise. The Poisson noise is typically available in radiography images. In the image sensor the dark current leakage is processed by Poisson noise and it will produce noise type known as “dark shot noise”.

$$P(\text{k events in interval}) = \frac{e^{-\lambda t}}{k!}) \quad (5)$$

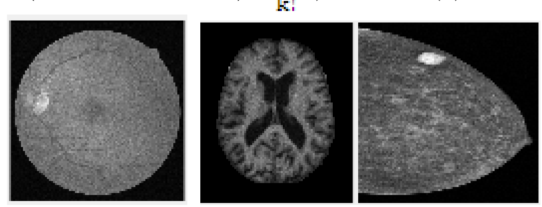

Fig. 4: Poisson noise effected images of Retinal, MRI & Mammogram.

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III. ALGORITHMS FOR IMAGE FILTERING

Filtering is a technique in which the image will be transformed by changing its intensity values with the help of a known filter to achieve the required characteristics which performs transforming the pixel intensity values to get the characteristics of Image enhancement, smoothing, Matching template. The Filtering is removing unwanted noises from images. In fundus images are often corrupted by random variations in intensity, illumination, or have poor contrast and can't be used directly etc., and noises are detected and removed by various filters. The filter is generally derived from frequency domain in medical images. In image processing the filters are processed either conquer the high frequency filters i.e. Sharpening useful for emphasizing transitions in image intensity or in low frequencies images i.e. Smoothening is reducing the noise and eliminate the small noises. Compare to the frequency domain the spatial domain is very less processing time. In which the image enhancement is performed by spatial domain to achieve the point and mask processing. There are two categories of filters namely linear and nonlinear filters. Linear filter is used to remove the certain noises and also sharpening the blur edges. In Linear filtering the processing time is very less and faster processing is achieved and poor edge detection is involved. In non-linear filters the edges are detected very sharply and due to this the time is more to process and slow processing time. In this paper the filtering is achieved by spatial domain rather than the frequency domain.

A. Average Filter (Mean Filter)

The mean filter is linear type filtering method. The mean filter smoothing the image data, it will remove the noise. This filter is mainly used or applied in masks over each pixel in the image one after another. The performance of each pixel mask are averaged together to make distinct pixel from other pixels, hence it is called average filter. Mainly in photographic images (i.e. In fundus photographic images) the grain noises are removed using this mean filter also this filter performs the spatial filtering on each specific pixel in an image using the grey level values in a square or rectangular neighbouring area in each image pixel. This mean filter also called convolution filter.

$$f(x,y) = \frac{1}{mn}\sum_{(s,t)\epsilon s_{xy}} g(s,t) \qquad (6)$$

Where f(x,y) value of restored image at point (x,y)

B. Median Filter

Linear filter combine with other filter reduces the noise in the fundus images. In the median filter the adjacent pixels will be almost same value as the reference pixel. When the linear filter is used the edges are blurred so the problem of blurring edges can be overcome by used non-linear filter. Median filter is a nonlinear filter. In the median filter the steps vector median filter. Vector median filter select from the set of vector only. The one of the vector will be closest to all the other vectors. When colour median filter is applied twice the images which are produced are sharp and without noise. Depending upon the noise density the images after the filtering also changes. It is represented as

$$m(u,v) = \text{median}\{g(a,b)\},\ (a,b) \in S_{xy} \qquad (7)$$

This filter is very good in removing noise, without the effects of smoothing that can happen with particular smoothing filters, generally salt & pepper noise is removed. It also removes impulsive noise, by smoothing the noise, Distortion is reduced.

C. Weiner Filter (Optimal Filter)

Weiner filter is the mean square error ideal linear filter for images corrupted by additive noise and blurring. The Weiner value is calculated by the signal and a noise process of the random second order stationary. This filter is always useful in Fourier domain. Weiner filter is optimal low pass filter in flourier transform, in spatial (pixel) type it is applied to difference among an image and a smoothed image. The overall mean square error in the method of reverse filtering and noise flattening is decreased. Weiner filter is performing the linear valuation over the original image. Given a corrupted image x (n, m), one takes the Discrete Fourier Transform (DFT) to obtain A (u, v).

The original image band is valued by taking the product of A (u, v) with the Weiner filter
W (u, v):

$$B(u,v) = W(u,v)\,A(u,v) \qquad (8)$$

Weiner Filter,

$$W(u,v) = \frac{H*(u,v)\,p_g(u,v)}{|H(u,v)|\,p_g(u,v) + p_n(u,v)} \qquad (9)$$

D. Ordered Statistic Filter

Order-Statistics filters are non-linear filters whose response depends on the ordering of pixels encompassed by the filter area. When the centre value of the pixel in the image area is replaced by 100th percentile, the filter is called max-filter. On the other hand, if the same pixel value is replaced by 0th percentile, the filter is termed as minimum filter.

Order statistic filters are spatial filters whose response is based on ranking the pixels contained in the image area encompassed by the filter. The response of the filter at any point is determined by the ranking result. If *x* is the location of pixel and its neighbourhood pixels are *y* and Ω_I (N) be the set of points $\{x+(i, j)\}$, here *i*, *j* should be in between -*N* and +*N* , in a (2*N*+1)x(2*N*+1) neighbourhood centred at x for positive and negative integer *N* .

If N > 2then $\Omega^0_x = \Omega_x$ represents the set of points in a 5x5 neighbourhood of *x*. For each point *y* which belongs to Ω^0_x, the absolute difference in the intensity of the pixel is defined by $d_{x,y} = |I_x - I_y|$.After taking all the differences between the neighbourhood pixels with centred pixel, choose *m* smallest values of neighbourhood pixels, and then sort these $d_{x,y}$ values in ascending order. Thus this statistic gives a measure of how close a pixel value is to its *m* most similar neighbors.

$$R(x) = \sum_{i=1}^{m} S_i \qquad (10)$$

The value of *R*(*x*) is very simple to introduce into existing filters.

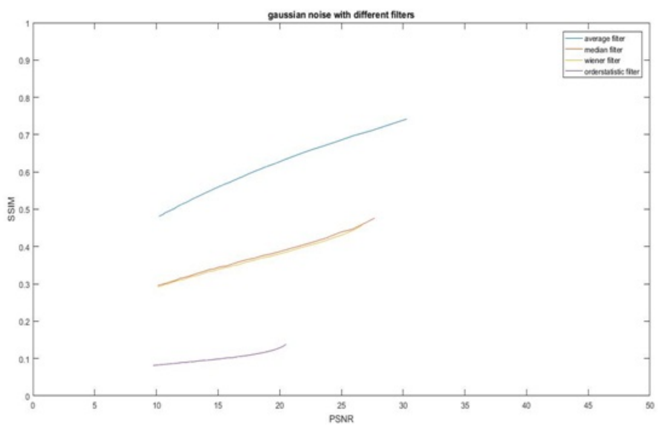
A new weighting function is incorporated into bilateral filter to implement trilateral filter. Bilateral filters are used to remove Gaussian noise. It retains the sharpness of edges. Each pixel is replaced the weighted average of the intensities in the neighborhood.

IV. INVESTIGATIONAL RESULTS AND CONCLUSION

For the assessment of effectiveness of filter some international metrics have been considered. They are PSNR (peak signal to noise ratio), MSE (mean square error), SSIM (structural similarity index measure). PSNR of the reconstructed image depends on the image's corresponding pixel values with the original image. The ideal value for PSNR is infinite. In practical reconstructed image is never the same as original and the practical values are around 30 dB to 60db. Similarly,

SIM gives the structural similarity of the de-noised image with the original image. The ideal value is 1. The mean square error is the error between pixel values which should approach zero.

- As PSNR practical value or acceptable value is >30db
- SSIM practical value or acceptable value is >0.9
- MSE practical value or acceptable values is around 10



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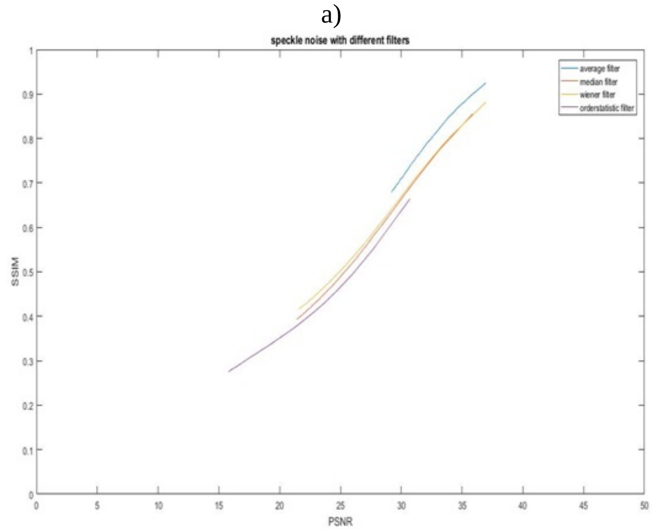

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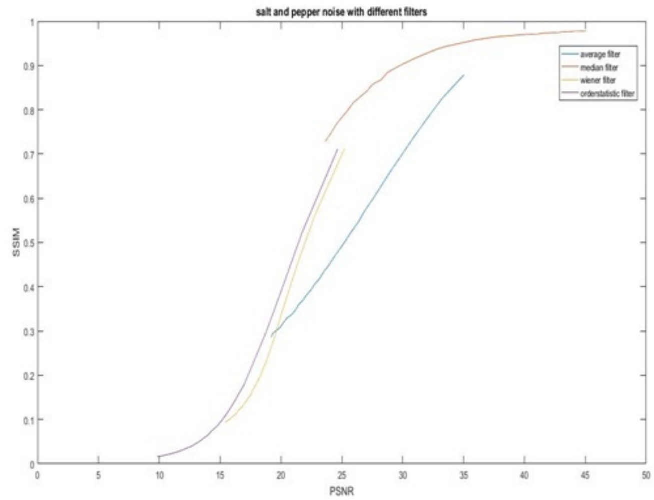

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Fig. 4: PSNR Vs SSIM graphs of different filters for a) Gaussian, b) salt and pepper c) speckle noise.

Different types of noises affect the image at different levels. To check the filter effectiveness according to variance change of noise PSNR versus SSIM graphs are drawn for different images for different noises for a set of variances. By the above sample graphs depending on the variance levels the filter's effectiveness can be determined for specific noise. For overall performance of filter for different noises bar graphs are plotted for PSNR, SSIM and MSE individually. By analyzing each bar graph the best suited filter is concluded.

Table 1 PSNR Values for Retinal Image

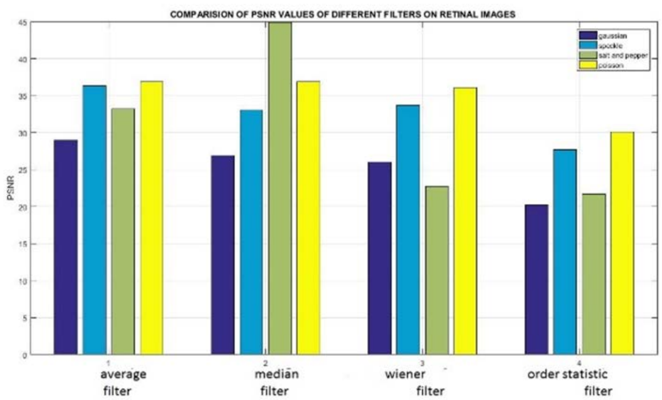
PSNR	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	28.9532	36.2890	33.2294	36.8822
Median Filter	26.9038	33.0352	44.8892	36.8983
Wiener Filter	26.0268	33.7201	22.7301	36.1172
Order statistic Filter	20.3919	22.6845	21.6741	30.1072

Table 2 MSE Values for Retinal Image

MSE	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	6.6643	5.2468	5.1618	5.4871
Median Filter	26.0305	8.8279	1.0757	6.9104
Wiener Filter	22.8777	6.5712	2.3219	7.8350
Order statistic Filter	60.4125	27.2146	0.9793	26.7443

Table 3 SSIM Values for Retinal Image

SSIM	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	0.7236	0.9104	0.8239	0.9220
Median Filter	0.4587	0.7731	0.9780	0.8779
Wiener Filter	0.4423	0.7964	0.5584	0.8596
Order statistic Filter	0.1328	0.5513	0.5188	0.6183



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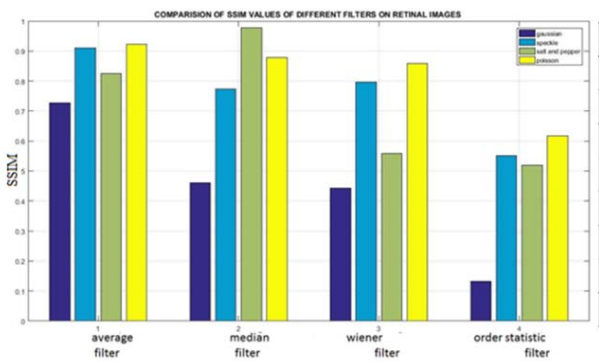

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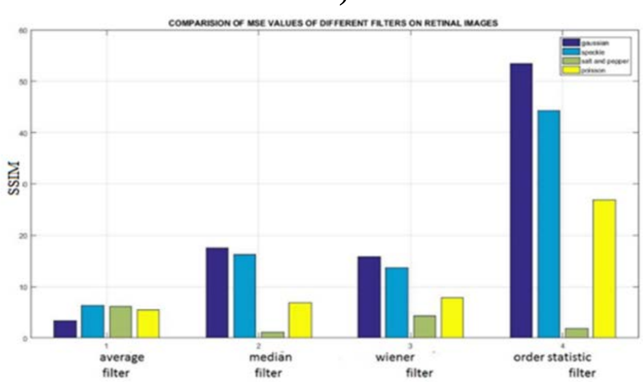

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Fig. 5 a) PSNR b) MSE c) SSIM Performance Metrics For Retinal Images Filtered By Average, Median, Wiener And Order Statistic Filters Affected By The Noises Like Gaussian, Speckle, Salt And Pepper And Poisson Noises.

Table 4 PSNR Values for Brain MRI

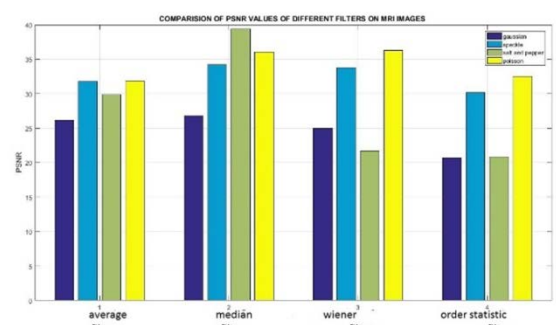
PSNR	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	26.3239	31.7767	29.9208	31.8933
Median Filter	26.9045	34.1056	39.0355	36.1053
Wiener Filter	25.0822	33.7511	21.7394	36.3432
Order statistic Filter	20.7889	30.1233	20.8912	32.5390

Table 6 MSE Values for Brain MRI

Table 5 SSIM Values for Brain MRI

MSE	Gaussian noise	Speckle noise	Salt & Pepper noise	Poisson noise
Average Filter	8.1543	16.0881	16.2359	15.7626
Median Filter	12.9238	13.1668	2.8768	8.1521
Wiener Filter	13.6100	12.5611	7.0531	7.1365
Order statistic Filter	34.3816	22.9993	1.3596	15.0078

SSIM	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	0.4379	0.9035	0.7190	0.9059
Median Filter	0.4612	0.9409	0.9837	0.9609
Wiener Filter	0.3813	0.9355	0.6440	0.9614
Order statistic Filter	0.2282	0.8861	0.6375	0.9165



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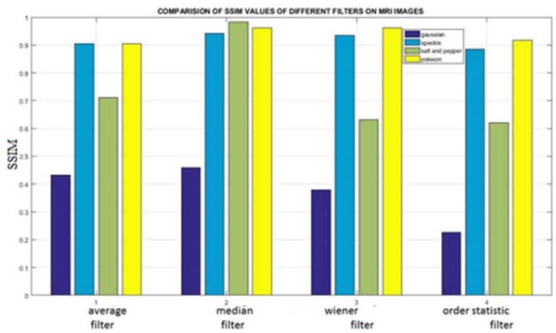

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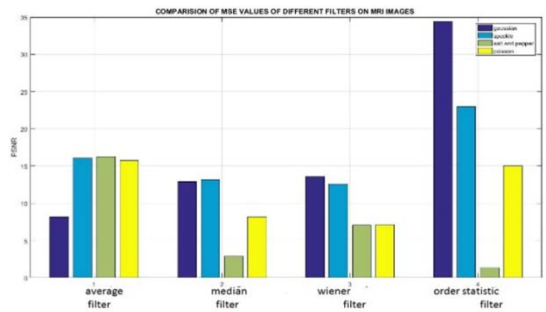

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Fig. 6 a) PSNR b) MSE c) SSIM performance metrics for Brail MRI images filtered by average, median, wiener and order statistic filters affected by the noises like Gaussian, speckle, salt and pepper and Poisson noises.

Table 7 PSNR Values for Mammograms

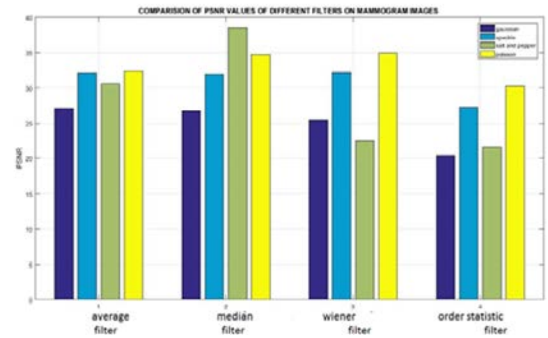
PSNR	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	27.0920	32.0922	30.6298	32.3910
Median Filter	26.6852	31.8938	38.5394	34.7215
Wiener Filter	25.3870	32.0328	32.5233	34.9347
Order statistic Filter	20.3816	27.2510	21.5163	30.1750

Table 8 MSE Values of Mammograms

MSE	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	8.7290	16.7362	15.8557	15.4129
Median Filter	16.1302	21.1353	4.8211	11.3729
Wiener Filter	13.2457	17.2901	7.9351	9.9885
Order statistic Filter	45.5757	43.2963	1.7238	25.3463

Table 9 SSIM Values for Mammograms

SSIM	GAUSSIAN NOISE	SPECKLE NOISE	SALT & PEPPER NOISE	POISSON NOISE
Average Filter	0.5162	0.8303	0.7042	0.8363
Median Filter	0.4685	0.8246	0.9499	0.8871
Wiener Filter	0.4113	0.8553	0.5867	0.9009
Order statistic Filter	0.1826	0.6870	0.5783	0.7739



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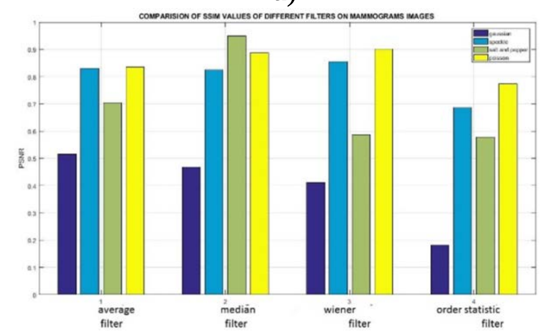

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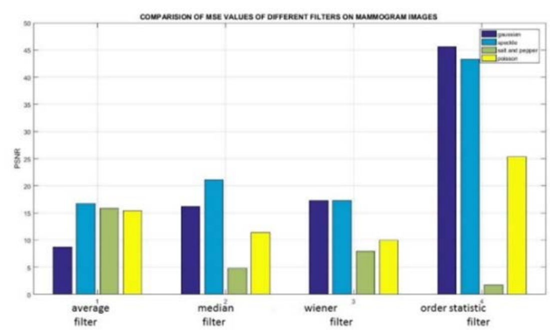

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Fig. 7 a) PSNR b) MSE c) SSIM performance metrics for Mammogram images filtered by average, median, wiener and order statistic filters affected by the noises like Gaussian, speckle, salt and pepper and Poisson noises.

V. CONCLUSION

By considering all the three bio-medical images like Retinal, Brain MRI, Mammograms, which are effected by noises. After applying different de-noising techniques we can conclude that Median filter is best suited for de-noising [10] the images including different dominant noises with

- Salt & Pepper noise in Retinal images
- Rician noise in Brain MRI
- Quantum noise in Mammograms

It is analyzed that these dominant noises can be removed by using Median filter affectively.

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