I J C T A, 9(2) 2016, pp. 419-433

Comparative Analysis of Various Filtering Techniques for Speckle Noise Suppression in Ultrasound Images

S. Sheela[1], M. Sumathi [2] and G. Nirmala Priya[3]

ABSTRACT

Image processing plays an important role in the field of Medicine because raw images are generally noisy due to various reasons like inherent noise of the equipment, physical mechanisms of the acquisition process...etc. Noise degrades the quality of images in terms of Suppressing edges, blurring the boundaries etc. In Ultrasound images, Speckle noise degrades the details of the image which makes the diagnostic process more complex. Noise removal is a very challenging issue in the Medical Image Processing as preservation of details is very important to identify the presence of a disease. Also, it helps the physician to diagnose the diseases as easy as possible. With this information, this paper reviews various filtering techniques for removing the noise present in the image and also compares the performance of the filters based on the parameters like Mean square Error, Signal to Noise Ratio and Peak Signal to Noise Ratio.

Keywords: Speckle Noise, Noise Reduction, Filters and Ultrasound Images.

INTRODUCTION

During acquisition and transmission, images are mostly corrupted by additive noise and that noise is modeled as Gaussian noise most of the time. The purpose of an image denoising algorithm is to reduce the noise level, and preserve the features of the image. Image denoising is often used in the field of photography or publishing where an image is degraded and needs to be improved before it can be printed. For this type of application the degradation process is to be analyzed in order to develop a model for it. When a model for the degradation process is developed the inverse process can be applied to the image to restore it back to the original form. This type of image restoration is often used in space exploration to help in eliminating artifacts generated by mechanical jitter in a spacecraft or to compensate the distortion in optical system of a telescope. Image denoising finds applications in fields such as astronomy where the resolution limitations are severe, in medical imaging where the physical requirements for high quality imaging are needed for analyzing images of unique events, and in forensic science where potentially useful photographic evidence is sometimes of extremely bad quality. This paper concentrates on image denoising for medical images.

Various Imaging modalities like CT, MRI and Ultrasound imaging are useful tool to diagnosis and study the various types of diseases. Noise free image plays an important role in identification of diseases as soon as possible. This paper focuses on reduction of speckle noise among the several noises like salt and pepper, Gaussian and uniform noise...etc from ultrasound images.

Poly Cystic Ovarian Syndrome (PCOS) is an important research problem in the medical field. Polycystic ovaries contain a large number of cysts that are harmless and no bigger than 8mm, the women having this disorder are said to have PCOS. Ultrasound imaging has become a very important technology in diagnosis

[1] Research Scholar, Department of Electronics and Communication Engineering, Sathyabama University, Chennai, India

[2] Professor, Department of Electronics and Control Engineering, Sathyabama University, Chennai, India

E-Mail: [1]ssheela97@gmail.com, [2]sumagopi206@gmail.com and [3]nirmalaganeshs@yahoo.co.in

of PCOS. But ultrasound images are suffered with speckle noise which worsens the edges of the images. Due to the speckle noise, accuracy in detection of cysts is affected. In order to achieve correct diagnosis, the ultrasound images have to be filtered to remove speckle noise. (Hiremath *et al.*, 2013).

Reviewing various types of noises occurred in an images and several types of image filters explains various technological aspects such as how the noise occurred in an image , what are the filters used to suppress those noises…etc. An effort has been taken to compare the performance level of various filters used in medical image processing. This paper is prepared in such a way that the Noise models describes the various noise occurred in an image, Filtering Techniques explains various filters used to suppress the noise, Image Assessment Parameter deals with parameters which is used to analyze the performance level of the filter in accordance with noise removal and finally, ends with the results and conclusive comment that the best quality of image is obtained using Wavelet and Homomorphic filter.

NOISE MODELS

Noise is caused due to random fluctuations in brightness and color information. It is the unwanted information present in the image which degrades the quality of the image. During acquisition process, the optical signal is converted into electrical signal. At each stage, this conversion experiences a fluctuation which adds some random value to the intensity of the pixel. Some factors which cause noise in digital images are:

- Environmental conditions during image acquisition.
- Quality of image sensing element
- Interference in the transmission channel

There are various types of noises occurs in images. They are,

a. Uniform Noise
b. Salt and Pepper Noise
c. Speckle Noise
d. Gaussian noise
e. Poisson Noise

(a) Uniform Noise

The uniform noise is caused by quantizing the pixels of image to a number of distinct levels which is also known as quantization noise. It has uniform distribution. In the uniform noise the level of the gray values of the noise are uniformly distributed across a specified range. Uniform noise can be used to generate any different type of noise distribution. This noise is often used to degrade images for the evaluation of image restoration algorithms. This noise provides the most neutral or unbiased noise. (Bhavik *el al.*, 2014)

$$p(z) = \begin{cases} \dfrac{1}{b-a} & if\ a \le z \le b \\ 0 & otherwise \end{cases} \tag{1}$$

(b) Salt and Pepper Noise

It is called so because of the presence of black and white dots present in the noisy image. It is also called as impulse noise, random noise, independent noise or spike noise. This is caused by failure of the memory cell, malfunctioning pixel elements in camera sensor and due to synchronization errors in image digitizing.

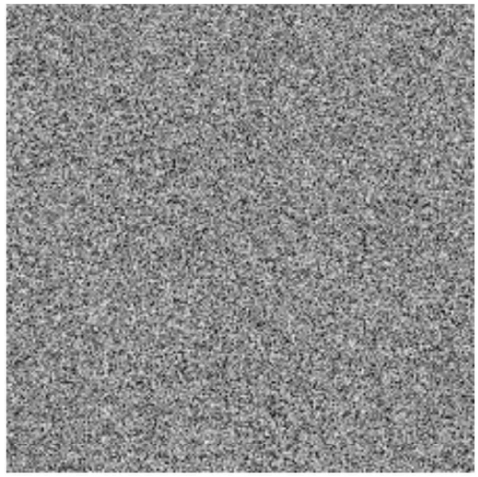

Figure 1: Uniform noise

This occurs during quick transients. These noises has only two possible values and the probability of each is less than 0.1.The intensity value for pepper noise is 255 and that of salt noise is zero. Median filter and Morphological filter can be used to remove salt and pepper noise. (Ajay *et al.*, 2015)

$$p(z) = \begin{cases} p_a & for\ z = a \\ p_b & for\ z = b \\ 0 & Otherwise \end{cases} \tag{2}$$

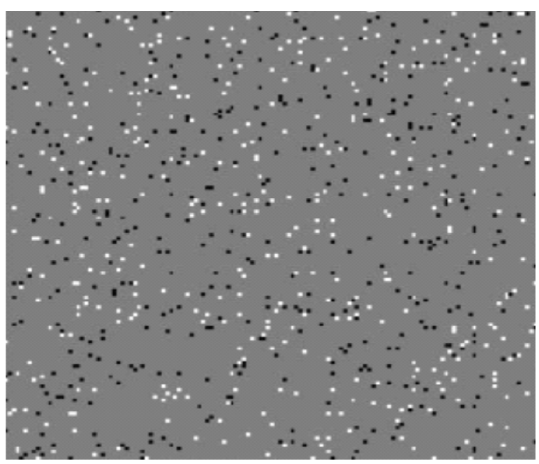

Figure 2: Salt and pepper noise

(c) Speckle noise

Speckle noise is a type of granular noise. This noise occurs in SAR (Synthetic Aperture Radar) and Ultrasound images. The light and dark pixel in an image is known as Speckle Noise which is produced, when radar waves interferes constructively or destructively. Speckle noise is commonly observed in any type of remotely sensed image utilizing coherent radiation. The active sensor emits the waves which travels in phase and interact to the target area. After interaction with the target area, due to the different travelling distance, these waves are in out of phase. This leads to produce light and dark pixels known as speckle noise. (Parminder *et al.*, 2014). It is a multiplicative noise. Reducing the effect of speckle noise is important for both better discrimination of scene targets and easier automatic image segmentation. Generally spatial filtering is used to reduce the speckle noise. No matter which method is used to reduce the effect of speckle noise, the speckle reduction method preserves the edges between different areas and textural information. (Beshiba *et al.,* 2013).

$$p(z) = \frac{z^{\alpha-1}}{(\alpha-1)!a^{\alpha}} e^{-\frac{z}{a}} \tag{3}$$

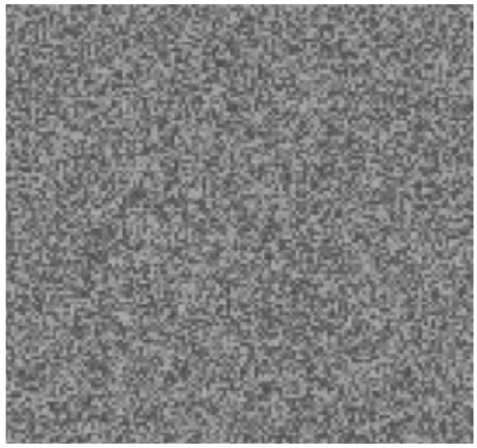

Figure 3: Speckle noise

(d) Gaussian noise

It is also known as amplifier noise. It is additive in nature and follows Gaussian distribution. It has a Probability distribution function of the normal distribution. It supports tractability in both spatial and frequency domain. It is statistical in nature. White Gaussian noise is the special case of Gaussian noise which is statistically independent. It is caused by poor illumination or high temperature or during transmission. This noise can be reduced using spatial filters. (Bhavik *et al.,* 2014)

$$p(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}} \tag{4}$$

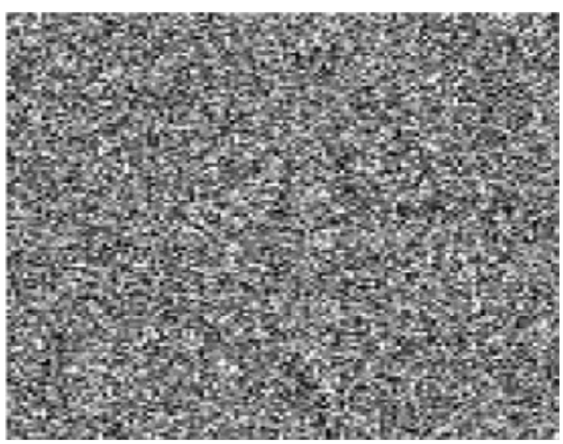

Figure 4: Gaussian noise

(e) Poisson noise

It is also called as shot or photon noise. It occurs when the number of photons sensed by the sensor is not sufficient to provide the required information. Here different pixels are suffered by independent noise values. (Bhavik *et al.,* 2014).

FILTERING TECHNIQUES

Image de-noising is an important task in image processing. Various filtering techniques are used to remove the noise completely from the image, by preserving the details. There are 2 major types of filtering namely linear filtering and nonlinear filtering.

Filter Description

Figure 5: Filter Description

where, g(x,y) = Corrupted image

f(x,y) = Filtered image

Linear Filters

Linear filters are used to remove certain type of noise. Gaussian or Averaging filters are suitable for this purpose. These filters also tend to blur the sharp edges, destroy the lines and other fine details of image, and perform badly in the presence of signal dependent noise. (Priyanka et al., 2013)

(a) Mean Filter

It falls under the category of linear filters. Mean filter is also known as averaging filter since it replaces the center pixel value with the average value of all the pixels. This is done by applying mask over pixel and the components are averaged to form single pixel. It is a simple spatial filter. Here the window is usually a square i.e., N*N but it can be of any shape. (Priyanka et al., 2013)

Advantages

- It removes grain noise.
- It provides smoothness to an image by reducing the intensity variations between adjacent pixels.

Disadvantages

- Edge preserving is relatively poor.

(b) Weiner Filter

Weiner filter is used to filter the image which is corrupted by noise. It follows statistical approach. This filter requires prior knowledge of spectral properties of the original signal and the noise. (Priyanka et al., 2013).

Advantages

- It is used to remove the blur present in the images.
- It removes overall mean square error.

Disadvantages

- It can handle only additive noise.
- It only provides a point estimate.

Non-Linear Filters

In recent years, a variety of non-linear median type filters such as rank conditioned, weighted median, relaxed median, rank selection have been developed to overcome the shortcoming of linear filter.

The different types of Linear and Non-Linear Filters are:

(a) Median Filter

It is a nonlinear filter. This filtering is done by finding the median value and replacing that value with each entry in the window. Median is just the center value after sorting all the values present in the window in ascending order. If the window contains odd number of values then the median is simple. If it has even number of values there will be multiple center values. (Priyanka et al., 2013). Median filter algorithm is as follows:

1. Select a two dimensional window W of size N*N.
2. Assume the pixel to be processed as Cx,y.
3. Find the median value of the pixels.
4. Replace Cx,y with the median value.
5. Repeat the steps 1 to 3, until all the pixel values get replaced.

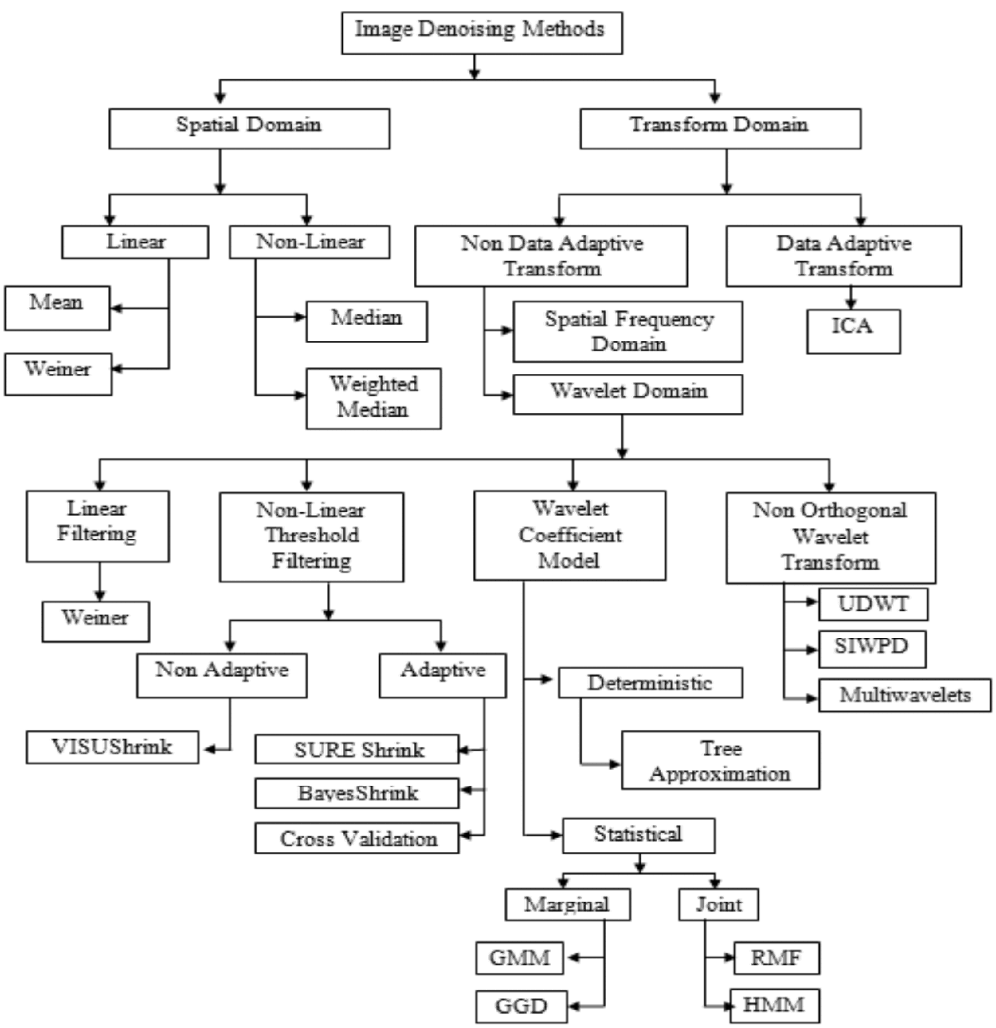

Figure 6: Block diagram of various denoising methods

Advantages

- It is used to eliminate the effect of input noise values with extremely large magnitudes.
- Best suited for salt and pepper noise.

Disadvantages

- It is very expensive and involves complex computation.
- This filter is relatively slow than other filters.

(b) Fourier Filter

The main objective in medical images is to find the filtering function which is used to suppress Fourier transform's high frequency components. Fourier transform properties are used in Fourier filter. Once the Fourier transform's high frequency component is minimized, using inverse Fourier transform the output image will be obtained. Two types of filters are Ideal filter and Butterworth filter.

(c) Homomorphic Filter

A filter which is used to remove multiplicative noise is Homomorphic filter. It is also used to enhance the brightness and contrast of the image. The high frequency components representing reflectance are increased while the low frequency components representing illumination are decreased to make the illumination of the image uniform. These illumination variations are considered as multiplicative noise which can be reduced by filtering in the log domain. It is known as the illumination reflectance model which is used to overcome the poor illumination condition. (Sivakumar *et al.,* 2010)

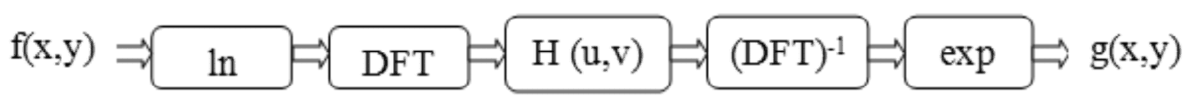

Figure 7: Block diagram of Homomorphic filter.

(d) Butterworth Filter

Butterworth filter is a frequency domain filter which produces output similar to the Gaussian smoothing in the spatial domain. The main difference between the spatial and frequency domain filter is that the computational cost of the frequency domain filters are independent of the filter function whereas the computational cost of the spatial filter increases with standard deviation. (Simily *et al.,* 2013).

(e) Wavelet filter

Wavelet transform has become a very popular transform in the area of analysis, de-noising and compression of images. The transform, which decomposes a signal or an image into a set of basic functions known as wavelets, is called wavelet transform. In this, Discrete Wavelet Transform (DWT) samples the wavelets discretely. The main advantage of the wavelet transform is, it captures both frequency and spatial information. In DWT, the image is decomposed into four sub-bands named as Low-Low1 (LL1), Low-High1 (LH1), High-Low1 (HL1) and High-High1 (HH1) which are formed by separable applications of horizontal and vertical filters. The LL1 represents the coarse level coefficient which is further decomposed to find the next coarse level of wavelet coefficients. This is known as two level wavelet decomposition technique which shown in Figure 8. (Joel *et al.,* 2013).

IMAGE ASSESSMENT PARAMETERS

During acquisition, transmission and reproduction, there is a chance of occurrence of distortions in an image which degrades the quality of an image. In Medical field, it is important to remove the noises from the images for proper analysis as well as early detection of various diseases using images.

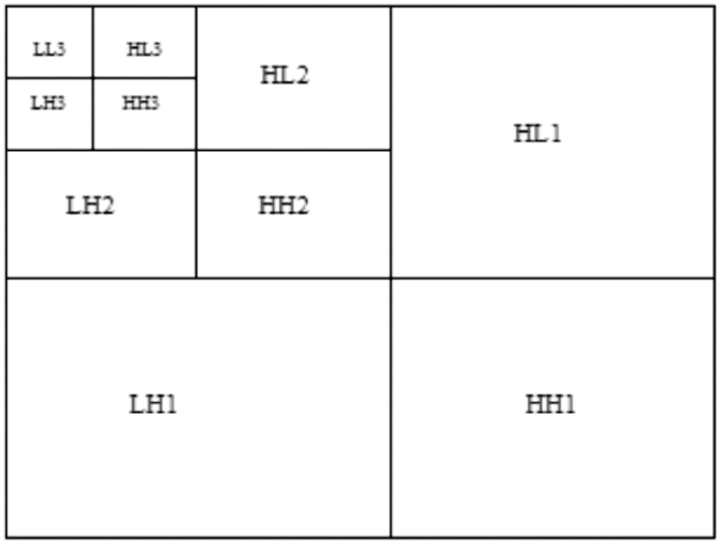

Figure 8: 2D wavelet transform

Various image assessment parameters are Signal to noise ratio (SNR) Peak (PSNR) signal to noise ratio and Mean square error (MSE),. In these parameters, MSE is used to quantify the difference between the estimated image and the original image. Lower value of MSE shows that the estimated image is closer to the original image. SNR and PSNR are used to show a relationship between the real image and the estimation error. High value of SNR and PSNR indicates an improvement.

$$MSE = \frac{1}{MN} \Sigma_{m=0}^{M-1} \Sigma_{n=0}^{N-1} [I(m,n) - I_e(m,n)]^2 \quad (5)$$

$$SNR = 10.\ \log_{10} \frac{\frac{1}{M.N} \Sigma_{m=0}^{M-1} \Sigma_{n=0}^{N-1} (m,n)}{MSE} \quad (6)$$

$$PSNR = 10.\ \log_{10} \frac{255^2}{MSE} \quad (7)$$

Where, I = Original Image.

Ie = Estimation of original image obtained from a noisy image.

M. N = Image's measurements.

IMPORTANCE OF DENOISING TECHNIQUES

In medical field, image processing plays a vital role because, noise in the scanned image causes several problems like patients need to be scanned again, consumes more time for analysis of image and mainly doctors cannot be able to identify the problems exactly for the treatment. This paper overviews several filters like median filter, wavelet filter…etc...which is used to remove the noise from the scanned image to enhance the quality of the image. Figure 9 shows Importance of Noise Reduction for Medical Applications.

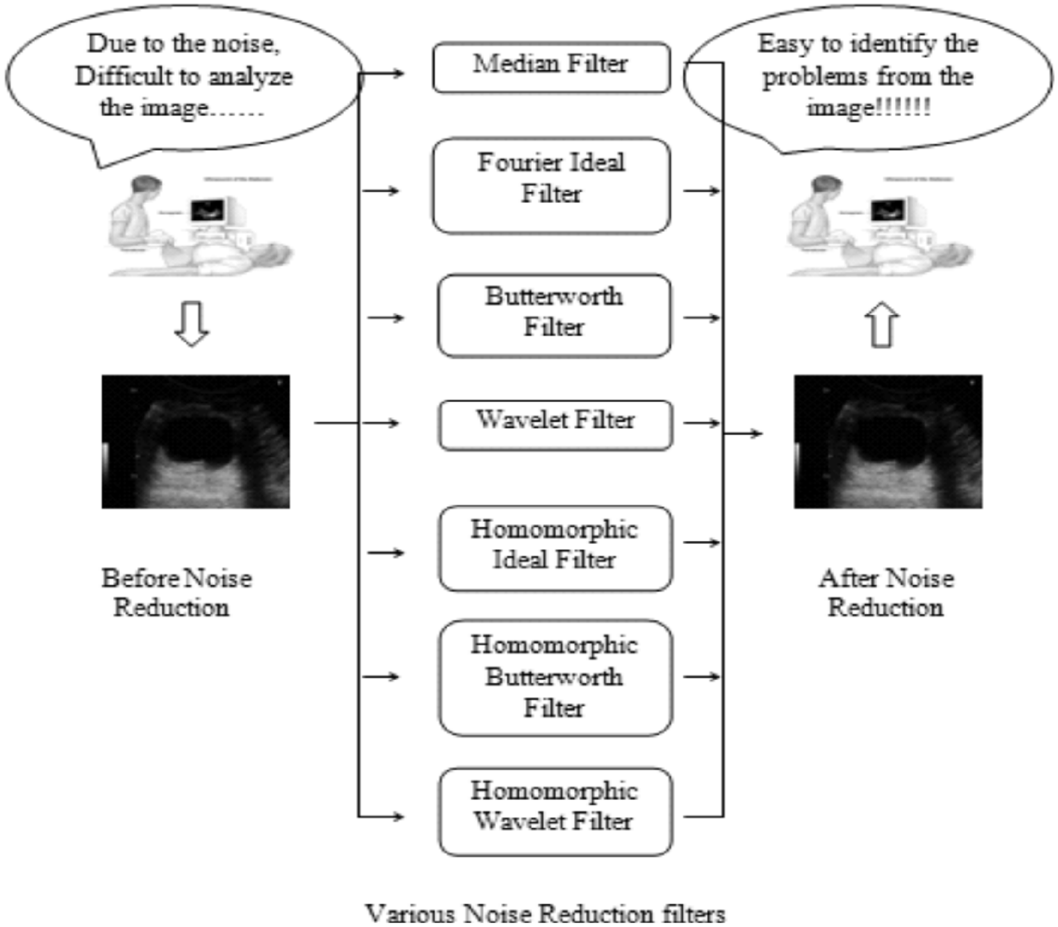

Figure 9: Importance of Noise Reduction for Medical Applications

RESULT AND DISCUSSION

The entire image processing work is carried out in Intel Core 2duo CPU @2.4GHz and the simulation results are observed using Matlab R2014a.The PCOS Ultrasound image shown in Figure- 10 is used to compare various filtering techniques. The size of this image is 246X177 pixels. Performance of various denoising algorithms studied using quantitative performance measures such as signal-to-noise ratio (SNR), peak signal-to-noise ratio (PSNR) and Mean Square Error (MSE). The output values obtained for this image are presented in the following Table- 1, 2, 3, 4, 5, 6 and 7. The denoised image obtained after applying various filters are shown in Figure 11, 12, 13, 14, 15, 16 and 17.

Figure 10: Reference image

Table 1
Metrics obtained when applying the Median filter

Filter	*Window*	*MSE*	*PSNR*	*SNR*
Median Filter	3 x 3	0.0008125	79.032405	72.344648
	5 x 5	0.0051896	70.979439	64.291682
	7 x 7	0.0154569	66.239571	59.551814
	9 x 9	0.0185575	65.445602	58.757845

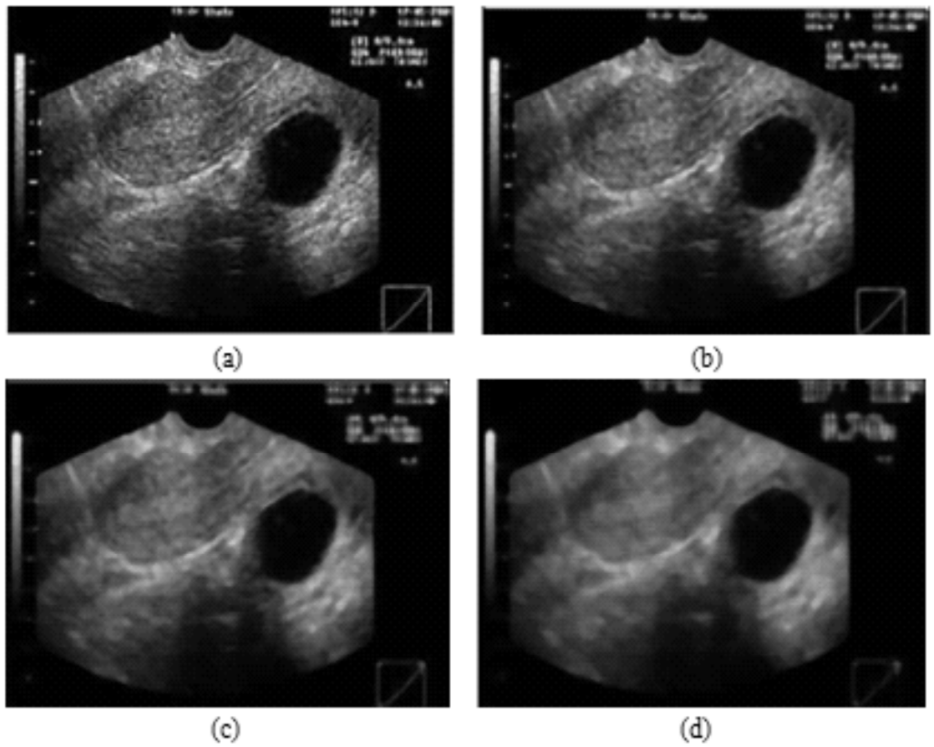

Figure 11: Images after applying the median filter with different window sizes (a) 3 x 3 window. (b) 5 x 5 window. (c) 7 x 7 window. (d) 9 x 9 window

Table 2
Metrics obtained when applying the Fourier Ideal Filter.

Filter	*Cutoff Freq*	*MSE*	*PSNR*	*SNR*
Fourier Ideal Filter	10	0.023401741	64.43832185	57.75056481
	30	0.01816687	65.53800255	58.85024552
	40	0.015474288	66.23469673	59.54693969
	50	0.013262304	66.90461371	60.21685667

Table 3
Metrics obtained when applying the Butterworth Filter

Filter	*Cutoff Freq*	*MSE*	*PSNR*	*SNR*
Butterworth Filter	10	0.02201315	64.703981	58.016224
	30	0.01679699	65.878488	59.190731
	40	0.01380396	66.730764	60.043007
	50	0.01139737	67.562755	60.874998

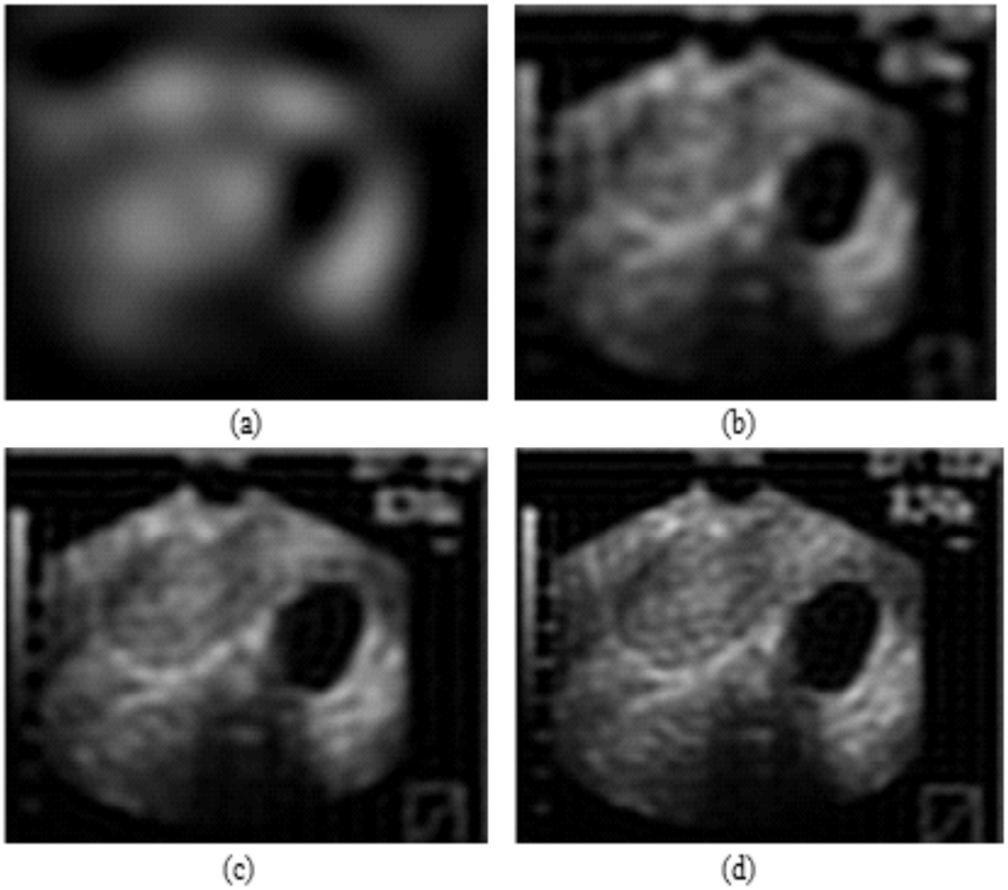

Figure 12: Images after applying Fourier idea filter with different cutoff frequencies. (a) Cutoff freq=10. (b) Cutoff freq =30. (c) Cutoff freq=40. (d) Cutoff freq=50

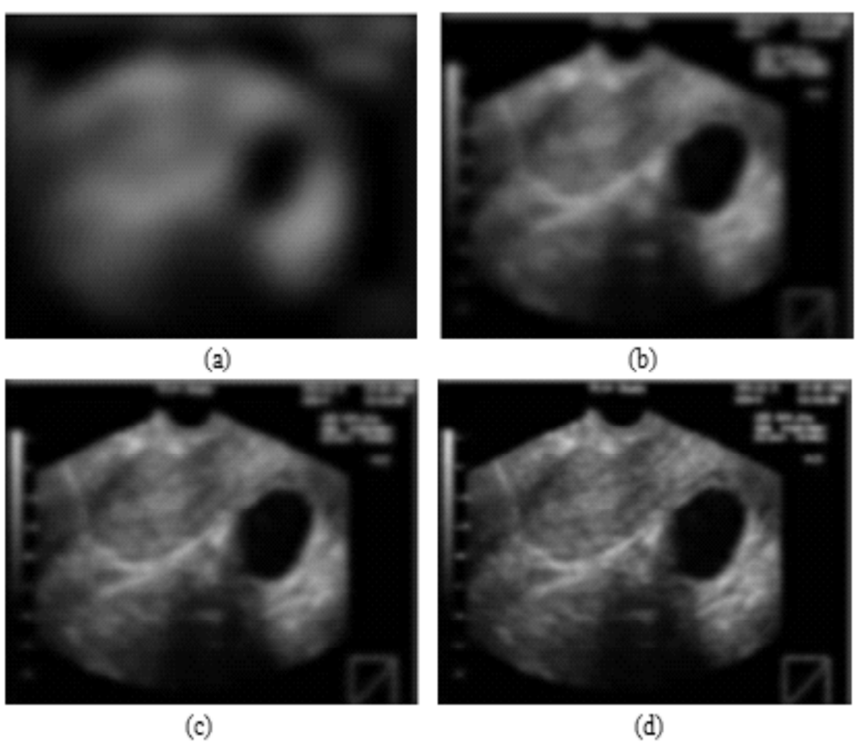

Figure 13: Images Images after applying Butterworth filter with different cutoff frequencies (a) Cutoff freq=10. (b) Cutoff freq =30. (c) Cutoff freq=40. (d) Cutoff freq=50

Table 4
Metrics obtained when applying the Wavelet Filter.

Filter	*Level*	*Band*	*MSE*	*PSNR*	*SNR*
Wavelet Filter	1	HL	0.0007086	79.626242	72.93848
	1	LH	0.0011959	77.353599	70.66584
	1	HH	5.6611	90.601775	83.91401
	2	HL	0.0882440	58.673949	51.98619
	2	LH	0.0907074	58.554375	51.86661
	2	HH	0.0906968	58.558830	51.86712
	2	LH-HH	0.0904900	58.564793	51.87703

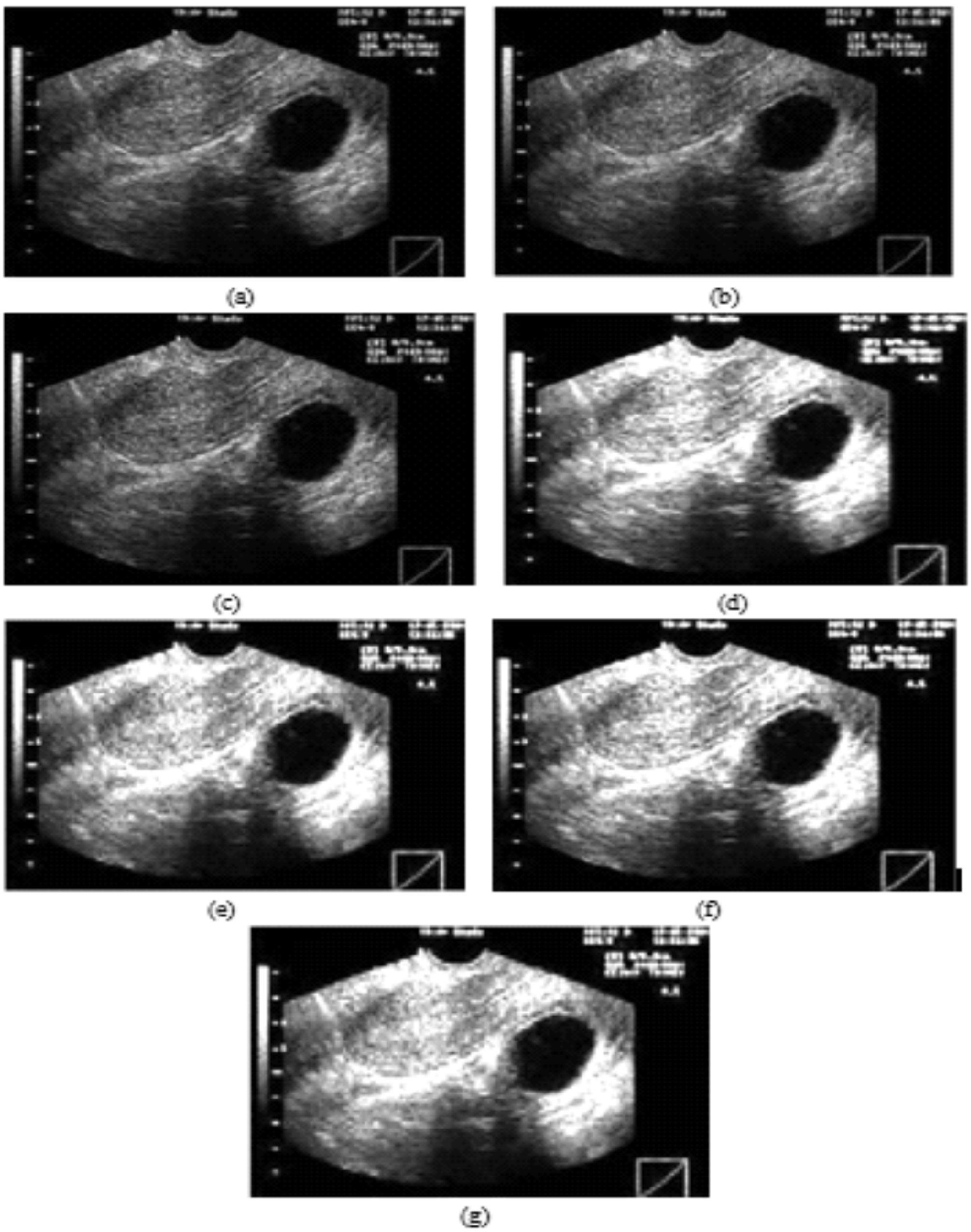

Figure 14: Images after applying Wavelet filter with different level-Band (a) 1-HL. (b) 1-LH. (c) 1-HH. (d) 2-HL. (e). 2-LH. (f). 2-HH. (g). 2-LH-HH

Table 5
Metrics obtained when applying the Homomorphic Fourier Ideal Filter.

Filter	*Cutoff freq*	*MSE*	*PSNR*	*SNR*
Homomorphic Fourier Ideal Filter	10	0.028000	63.659099	56.971342
	30	0.020880	64.933306	58.245549
	40	0.017773	65.633172	58.945415
	50	0.015141	66.329150	59.641393

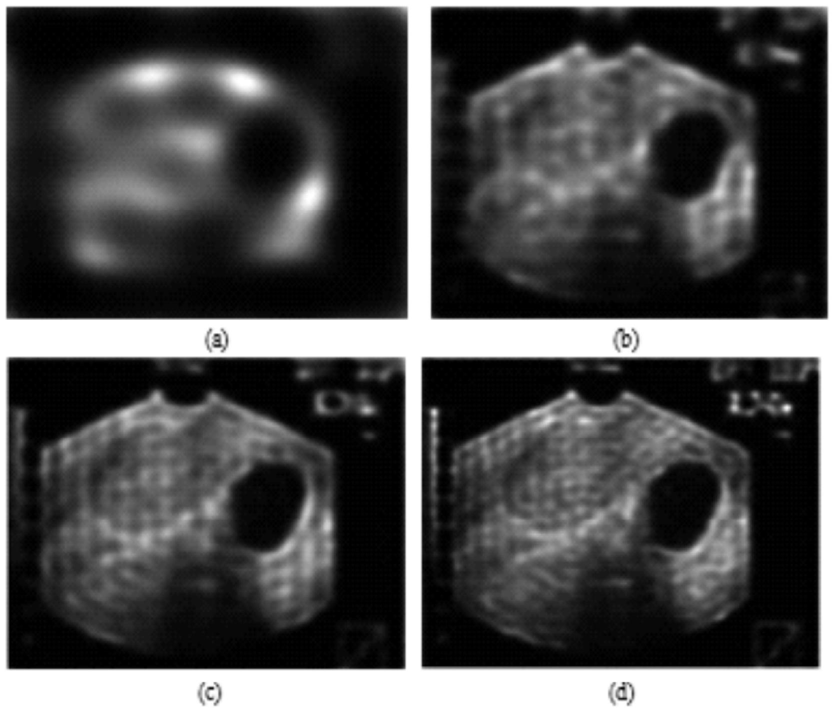

Figure 15: Images after applying Homomorphic Fourier ideal filter with different cutoff frequencies. (a) Cutoff freq=10. (b) Cutoff freq =30. (c) Cutoff freq=40. (d) Cutoff freq=50.

Table 6
Metrics obtained when applying the Homomorphic Fourier Butterworth Filter.

Filter	*Cutoff freq*	*MSE*	*PSNR*	*SNR*
Homomorphic Fourier Butterworth Filter	10	0.0241978	64.293043	57.605286
	30	0.0187783	65.394221	58.706464
	40	0.0158626	66.127035	59.439278
	50	0.0132682	66.902663	60.214906

Table 7
Metrics obtained when applying the Homomorphic Wavelet Filter.

Filter	*Level*	*Band*	*MSE*	*PSNR*	*SNR*
Homomorphic Wavelet Filter	1	HL	0.00078	79.17838	72.4906
	1	LH	0.00129	76.99609	70.3083
	1	HH	8.26704	88.95730	82.2695
	1	LH-HH	0.00132	76.91746	70.2297
	2	HL	0.02917	63.48088	56.7931
	2	LH	0.03012	63.34100	56.6532
	2	HH	0.02736	63.75818	57.0704
	2	LH-HH	0.03036	63.30712	56.6193

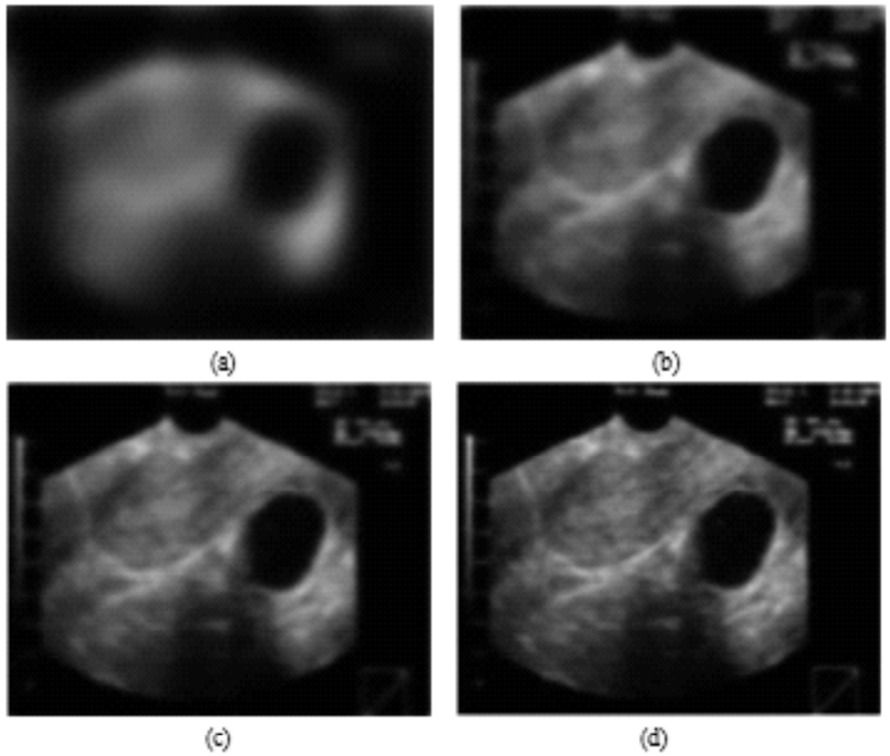

Figure 16: Images after applying Homomorphic Fourier Butterworth filter with different cutoff frequencies. (a) Cutoff freq=10. (b) Cutoff freq =30. (c) Cutoff freq=40. (d) Cutoff freq=50.

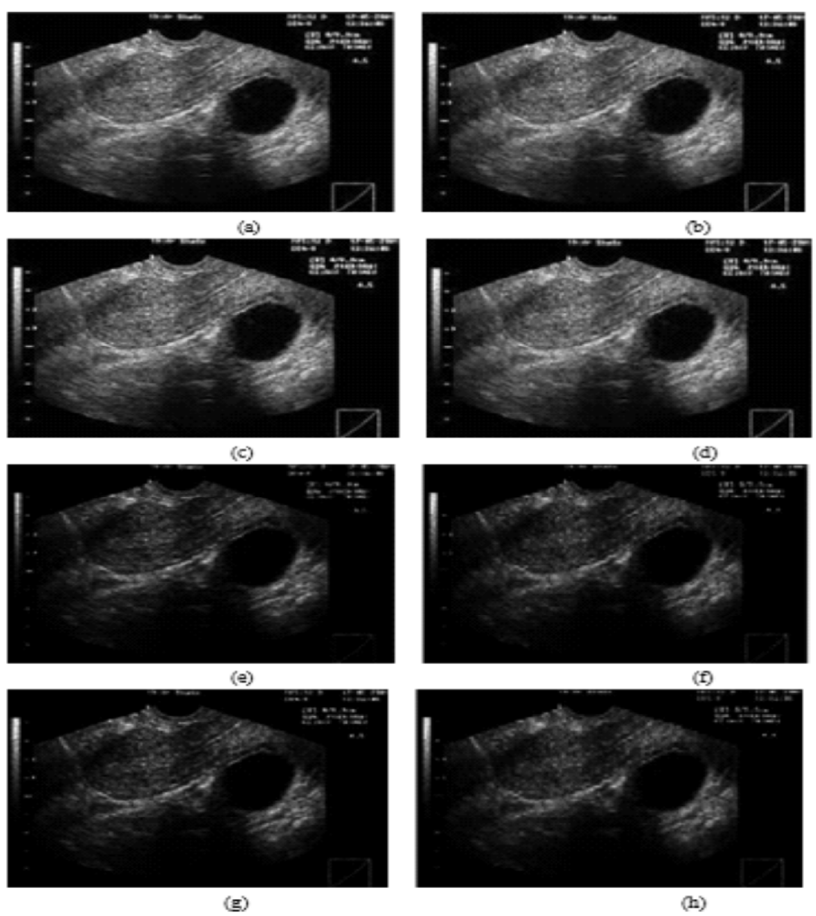

Figure 17: Images after applying Homomorphic Wavelet filter with different level-Band (a) 1-HL. (b) 1-LH. (c) 1-HH. (d). 1-LH-HH. (e) 2-HL. (f). 2-LH. (g). 2-HH. (h). 2-LH-HH

CONCLUSION

In this paper, various denoising techniques have been analyzed. Images in the medical field, such as magnetic resonance imaging, X-rays, ultrasound images, etc. are a very significant tool for the diagnosis of various diseases. This paper has focused on the suppression methods of the speckle noise in ultrasound images to smooth the existing noise in medical images. From this comparative study, it is concluded that the Wavelet filter in HL band and Homomorphic wavelet filter are suitable for suppression of speckle noise from PCOS ultrasound image as it observed lower mean square error and higher peak signal to noise ratio.

REFERENCES

[1] Ajay Kumar Boyat and Brijendra Kumar Joshi,” A Review Paper: Noise Models In Digital Image Processing”, Signal & Image Processing: An International Journal (SIPIJ) Vol.6, No.2, April 2015.

[2] Bhavik D. Maheta, Ratansing N. Patel and Kishol Bhamaniya,” Comparative Analysis of Image Denoising by Filtering Techniques”, International Journal for Scientific Research & Development| Vol. 2, Issue 03, 2014 | ISSN (online): 2321-0613.

[3] Parminder Pal Kaur, Tejinderpal Singh,” Speckle Noise Reduction in Ultrasound Images: Performance Analysis and Comparison”, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181.Vol. 3 Issue 7, July – 2014.

[4] T. Joel and R. Sivakumar,” Despeckling of Ultrasound Medical Images: A Survey”, Journal of Image and Graphics Vol. 1, No. 3, September 2013.

[5] Simily Joseph, Kannan Balakrishnan, M.R. Balachandran Nair and Reji Rajan Varghese,” Ultrasound Image Despeckling using Local Binary Pattern Weighted Linear Filtering”, I.J. Information Technology and Computer Science, 2013, 06, 1-9 Published Online May 2013 in MECS (http://www.mecs-press.org/) DOI: 10.5815/ijitcs.2013.06.01.

[6] Priyanka Kamboj and Versha Rani,” A Brief Study of Various Noise Model And Filtering Techniques”, Journal of Global Research in Computer Science, Volume 4, No. 4, April 2013.

[7] P.S Hiremath and Jyothi R Tegnoor,”Follicle Detection and Ovarian Classification in Digital Ultrasound Images of Ovaries”,http://dx.doi.org/10.5772/56518,2013.

[8] Ms. Alka Vishwa and Ms. Alka Vishwa,” Speckle Noise Reduction in Ultrasound Images by Wavelet Thresholding”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 2, February 2012.

[9] Jappreet Kaur, Jasdeep Kaur and Manpreet Kaur,” Survey of Despeckling Techniques for Medical Ultrasound Images”, Jappreet kaur et al, Int. J. Comp. Tech. Appl., Vol 2 (4), 1003-1007. IJCTA,July-August 2011.

[10] R. Sivakumar, Member IACSIT, M. K. Gayathri and D. Nedumaran, Member IEEE, IACSIT,” Speckle Filtering of Ultrasound B-Scan Images- A Comparative Study of Single Scale Spatial Adaptive Filters, Multiscale Filter and Diffusion Filters”, IACSIT International Journal of Engineering and Technology, Vol.2, No.6, December 2010.ISSN: 1793-8236.

[11] R. Sivakumar and D. Nedumaran,” Comparative study of Speckle Noise Reduction of Ultrasound B-scan Images in Matrix Laboratory Environment”, International Journal of Computer Applications (0975 – 8887) Volume 10– No.9, November 2010.

[12] S.Sudha, G.R.Suresh and R.Sukanesh,” Speckle Noise Reduction in Ultrasound Images by Wavelet Thresholding based on Weighted Variance”, International Journal of Computer Theory and Engineering, Vol. 1, No. 1, April 2009 1793-8201.

[13] G. Juan L. Mateo and Antonio Fernández-Caballero,”Finding out general tendencies in speckle noise reduction in ultrasound images”, Expert Systems with Applications 36 (2009) 7786–7797.