ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

IMAGE DENOISING IN MRI IMAGES USING CONTOURLET TRANSFORM AND COMPARISON OF FILTERING METHODS

A. Afreen Habiba[*1] & Dr.B.Raghu[2]
[*1]Research Scholar, Computer Science, Bharath University, Chennai
[2]Professor of Computer Science and Engineering, SVS Group of Institutions, Warangal

ABSTRACT

In diagnosis of medical images, operations such as feature extraction and object recognition plays the key role.. These operations will become difficult if the images are corrupted with noises. Several types of noise were introduced in the images during image acquisition, transfer & storage. The main objective is to remove the noise from the input image. Image Denoising is an utmost challenge for Researchers, developing Image denoising algorithms is a difficult task, since fine details in a medical image should not be destroyed during noise removal during the diagnosis of information. Medical image focuses on the speckle noise. So, several denoising filters are implemented and performance are compared to find the optimum filter. To the input image noise is added and various filtering are applied to remove the noise. The filters used are Wiener filter, Adaptive Fuzzy filter and Vector Median Filter. The frequency domain is used to improve the quality of the denoising method. As the first step Contourlet transform is applied to the noisy image. Further, several filters are applied on the transformed image for the effective removal of noise. The performance of the filters are compared based on PSNR, SSIM, IQI.

Keywords: MRI image, Contourlet transform, Speckle noise, Wiener filter, Adaptive Fuzzy filter, Vector Median Filter.

I. INTRODUCTION

Digital image processing is used widely in many essential fields such as medical imaging for diagnosis of diseases, face recognition for security purposes and so on. Image Denoising is a central pre-processing step in image processing to detach the noise in order to strengthen and recover small details that may be hidden in the data. The goal of denoising is to remove the noise, which may corrupt an image during its acquisition or transmission, while retaining its quality. Speckle noise is also known as multiplicative noise. It is similar to phasors with random amplitude and phase in free space . speckle noise can be treated as infinite sum of independents. Gaussian noise is statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pairs of times are statistically independent (and uncorrelated)[5]. The DWT analysis problems have been solved by the Contourlet Transform (CT) which can efficiently approximate a smooth contour at multiple resolutions. So, here using the Contourlet Transform & to give the best result.

Related Work

Image De-noising is used to produce good estimates of the original image from noisy observations. The recovered image should contain less noise than the observations while still keep sharp transitions (i.e edges)[9]- Image de-noising techniquesvary from simple thresholding to complicate model based algorithm. However simple thresholding methods can remove most of the noise.

Denoising is nothing but the removing noise from image while retaining the original quality of the image. The great challenge of image denoising is how to preserve the edges and all fine details of an image while suppression of noise. It still remains challenge for researchers as noise removal introduces artifacts and causes blurring of the images [7]. So, it is necessary to develop an efficient denoising technique to avoid such knowledge corruption.

Image noise is random variation of brightness or Color information in images , and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that adds spurious and extraneous information .Digital image noise may occur due to various sources. During acquisition process, digital images convert optical signals into electrical one and then to digital signals and are one process by which the noise is introduced in digital images. Due to natural phenomena at conversion process each stage experiences a fluctuation that adds a random value to the intensity of a pixel in a resulting image [33].

During acquisition or transmission MRI images are largely corrupted by noise. Also, noise is also made as a result of imperfect instrument used during processing, interference and compression [16]. Image noise can be defined as random variation of brightness or color information image produced by the sensor and circuitry of the scanner. Noise in MRI poses a lot of problem to medical personnel by interfering with interpretation of MRI for diagnosis and treatment of human .Image noise in large measures contributes high hazards faced by human [11].In the digital images like MRI, noise are low as well as high frequency components. Removing high frequency components is very easy as comparatively with low frequency components as real signal and low frequency noise can not be distinguished easily [16]. Noise in MRI mostly obeys Rician distribution. The term rician noise is used to the error between underlying image intensities and the observed data. As it has non zero mean , its mean depends on the local intensity in the image. Also, rician noise is signal dependent and particularly problematic in high resolution, low signal to noise ratio regime where it not only causes random fluctuations but also introduces as signal dependent bias to the data that reduces image contrast. As bias field signal is low frequency signal which corrupts MRI images because in homogenities in the magnetic field of MRI machines. It blurs the images and reduces the high frequency content of image such as edge, contours and also alters the intensity values of image pixels. Because of this tissues have different grey level distribution across image. Image processing algorithm like segmentation, classification or texture analysis use the grey level values of that image pixels which will not give satisfactory result. The preprocessing is required for correction of bias field signal before submitting corrupted MRI to such algorithm.[19] Rician noise affects the image in both quantitative and qualitative manner and thus it hinders image analysis, interpretation and feature detection [19].So denoising method is required which removes this noise.

Gaussian noise is statistical noise having a probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution[10].This noise model is additive in nature [8].Additive white Gaussian noise (AWGN) can be caused by poor quality image acquisition, noisy environment or internal noise in communication channels.

Speckle-noise is a granular noise degrades the quality of the active radar, synthetic aperture radar (SAR), and medical ultrasound images. Speckle noise occurs in conventional radar due to random fluctuations in the return signal from an object [13].

The Contourlet transform has been developed to overcome the limitations of the wavelets transform [30]. It permits different and elastic number of directions at each scale, while achieving nearly critical sampling.

The Contourlet transform can be worked Firstly, the Laplacian pyramid (LP) is used to decompose the given image into a number of radial subbands, and the directional filter banks (DFB) decompose each LP detail subband into a number of directional subbands. The band pass images from the LP are fed into a DFB so that directional information can be captured. The scheme can be iterated on the coarse image. The combination of the LP and the DFB is a double filter bank named Pyramidal Directional Filter Bank (PDFB), which decomposes images into directional subbands at multiple scales.The combination of the LP and the DFB is a double filter bank named Pyramidal Directional Filter Bank (PDFB), which decomposes images into directional subbands at multiple scales.There are many research works have used CT in different applications, especially in the field of denoising and distortions of the images.[6] have presented a Contourlet based speckle reduction method for denoising ultrasound images of breast. In [15], authors proposed a novel method for denoising medical ultrasound images, by considering image noise content as combination of speckle noise and Gaussian noise.[12] The method for extracting the image features using Contourlet Harris detector that is applied for medical image retrieval.[22]This is used to scale adaptive threshold for medical ultrasound image, wherein the subband Contourlet coefficients of the ultrasound images after logarithmic transform are modeled as generalized Gaussian distribution. [18] The proposed method is to determine the number of levels of Laplacian pyramidal decomposition, the number of directional decompositions to peform on each pyramidal level and thresholding schemes which yields optimal despeckling of medical ultrasound images, in particular. This method consists of the log transformed original ultrasound image being subjected to Contourlet transform, to obtain Contourlet coefficients. The transformed image is denoised by applying thresholding techniques on individual band pass sub bands using a Bayes shrinkage rule.

Wiener filtering carry out an optimal between inverse filtering and noise smoothing. It removes additive noise and deblurring concurrently. This proves to be optimal in reducing the overall Mean Square Error(MSE). The operation involves two parts. One is inverse filtering and the other is noise smoothing. Wiener filters belong to a kind of optimum linear filters with the noisy data as input which involves the calculation of difference between the desired output sequences from the actual output. The performance can be measured using Minimum Mean-Square Error.[4]

Fuzzy techniques are widely applied in the area of digital image restoration. Main achievements related are presented by four parts, in which the filters based on fuzzy rank selection, fuzzy weighted, fuzzy network (FNN) and soft-switching are systematically analyzed, respectively [28]. One drawback of fuzzy filters for multidimensional signals is that the signal is converted to a vector that ignores the relative position of the pixels. This adaptive fuzzy filter is considered for both cases of compressed images and video sequences. To assess the filter performance in reducing the flickering artifact, a novel flickering metric based on the metric in [24] is proposed with the extension of flickering consideration for motion areas. The spatial adaptation and directional adaptation make the proposed adaptive fuzzy filter different from the conventional bilateral filters, which adapt to the distance between pixels. Another adaptation of bilateral filters in the offset and the width of the range filter was discussed in [20],[26] and [23]. These locally adaptive methods require complicated training based approach and are only used for image enhancement.

The most popular vector filter is vector median filter (VMF). VMF is a vector processing operator that has been introduced as an extension of scalar median filter [32, 25]. To quantify relative magnitude differences of input samples, VMF utilizes either the well-known Euclidean distance or the generalized Minkowski metric. To improve detail-preserving characteristics of VMF, the simple basic idea has been modified and extended VMF-based filters [27,21,31] were designed.

Motivation and justification of the proposed work

The Contourlet transform(CT) is better than Discrete Wavelet transform(DWT) because it produce decomposed image coefficients. Similar to wavelet, contourlet decomposes the image into different scales. Unlike the wavelet contourlet decomposes each scale into arbitrarily power of two's number of directions. Wavelet transform gives frequency representation of raw signal at any given interval of time. The disadvantage of wavelet transform is to consider small coefficients are likely due to noise and large coefficient are likely due to important signal features.The DWT can find out line discontinuity only. It can't preserve edges, curves and some details.So, need to use contourlet transform.It is used to contour the regions. The main advantage of contourlet transform is that it has a double filter bank structure. It consists of a Laplacian pyramidal filter and a directional filter bank. The Laplacian pyramid (LP) is used to capture the point discontinuities. The directional filter bank (DFB) is used to link point discontinuities into linear structures. In this paper Contourlet transform is based on the filtering techniques for image denoising.

Outline of the Work

In this work denoising is Performed by Contourlet Transform and Filters.The system is expressed as Fig.1The input image is taken and then the noise is added in the image.

[Habiba, 4(7): July 2017] ISSN 2348 – 8034
DOI- 10.5281/zenodo.835762 Impact Factor- 4.022

Contourlet transform is applied to noisy image. And then apply the several filters on the transformed image.The applied Filters are namely,Wiener Filter,Adaptive Fuzzy Filter,Vector Median Filter.Finally,Inverse Contourlet Transform is applied and get the denoised image.

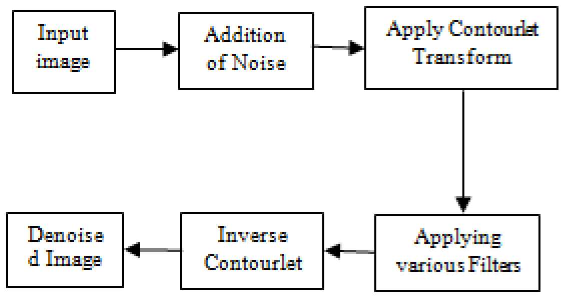


Fig.1.Block Diagram Of Image Denoising Using Contourlet Transform

The rest of the paper is organized as follows. The Methodologies are discussed in Chapter II. This includes Contourlet Transform, Noises and Filtering Techniques. Experimental results are shown in Chapter III. Performance Evaluation is discussed in Chapter IV.Finally conclusion is presented in Chapter V.

II. METHODOLOGY

Contourlet Transform

The contourlet transform is applied for the noisy image to produce decomposed image coefficients. Basically Contourlet transform is a double filter bank structure. It consists of a Laplacian pyramidal filter followed by a directional filter bank .First the Laplacian pyramid (LP) is used to capture the point discontinuities .Then directional filter bank (DFB) used to link point discontinuities into linear structures. Similar to wavelet, contourlet decomposes the image into different scales .Unlike the wavelet ,contourlet decomposes each scale into arbitrarily power of two's number of directions.

The contourlet transformation expression is given by,

$$\lambda^{(t)}_{j,k}(t) = \sum_{i-0}^{3} \sum_{n\in z^2} d_k^{(t)}[2n + k_i]\left(\sum_{m\in z^2} f_i[m]\,\phi_3 - 1,2n + m\right) \quad (1)$$ Where ,

$\lambda^{\omega}_{i,j}(t)$ represents the contourlet transformation of the image. The $d_k^{(l)}$ and $f_i(m)$ represents the directional filter and the band passfilter in the equation. Thus j, k and n represent the scale direction and location. Therefore l represents the number of directional filter bank decomposition levels at different scales j. Thus the output of contourlet transform is a decomposed image coefficients.[5]

Types of Noise

Gaussian Noise

Gaussian noise is statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pairs of times are statistically independent (and uncorrelated). In applications, Gaussian noise is most commonly used as additive white noise to yield additive white Gaussian noise. The probability density function of n-dimensional Gaussian noise is,

$$f(x) = \left((2\pi)^n detK\right)^{-1/2} \exp\left(-(x-\mu)^T K^{-1}(x-\mu)/2\right) \qquad (2)$$

Where x is a length-n vector, K is the n-by-n covariance matrix, μ is the mean value vector, and the superscript T indicates matrix transpose.[5]

Speckle Noise

Speckle noise is multiplicative noise unlike the Gaussian and salt pepper noise. This noise can be modeled by random vale multiplications with pixel values of the image and can be expressed as

$$P = I + n * I \qquad (3)$$

Where P is the speckle noise distribution image, I is the input image and n is the uniform noise image by mean o and variance v.[2]

Types Of Filters

Wiener Filter

The goal of the Wiener filter is to filter out noise that has corrupted a signal. It is based on a statistical approach. Typical filters are designed for a desired frequency response. The Wiener filter approaches filtering from a different angle. One is assumed to have knowledge of the spectral properties of the original signal and the noise, and one seeks the LTI filter whose output wouldcome as close to the original signal as possible[29]. Wiener filters are characterized by the following:

a. Assumption: signal and (additive) noise are stationary linear random processes with known spectral characteristics.
b. Requirement: the filter must be physically realizable, i.e. causal (this requirement can be dropped, resulting in a non-causal solution).
c. Performance criteria: minimum mean-square error.

Wiener Filter in the Fourier Domain

The Wiener filter is:

$$G(U,V) = \frac{H^*(U,V)P_s(U,V)}{|H(U,V)|^2 P_s(U,V) + P_n(U,V)} \qquad (4)$$

Dividing through by Ps makes its behavior easier to explain:

$$G(U,V) = \frac{H^*(U,V)}{|H(U,V)|^2 + \frac{P_n(U,V)}{P_s(U,V)}}$$

where

H(u,v) = Degradation function
H*(u,v) = Complex conjugate of degradation function
Pn(u,v) = Power Spectral Density of Noise
Ps(u,v) = Power Spectral Density of un-degraded image
The term Pn/Ps can be interpreted as the reciprocal of the signal-to-noise ratio.

Adaptive Fuzzy Filter

Fuzzy techniques are widely applied in the area of digital image restoration. Main achievements related are presented by four parts, in which the filters based on fuzzy rank selection, fuzzy weighted, fuzzy network (FNN) and soft-switching are systematically analyzed, respectively [28]. One drawback of fuzzy filters for multidimensional signals is that the signal is converted to a vector that ignores the relative position of the pixels. This adaptive fuzzy filter is considered for both cases of compressed images and video sequences. To assess the filter performance in reducing the flickering artifact, a novel flickering metric based on the metric in [24] is proposed with the extension of flickering consideration for motion areas. The spatial adaptation and directional adaptation make the proposed adaptive fuzzy filter different from the conventional bilateral filters, which adapt to the distance between pixels. Another adaptation of bilateral filters in the offset and the width of the range filter was discussed in [20],[26] and [23]. These locally adaptive methods require complicated training based approach and are only used for image enhancement.

[Habiba, 4(7): July 2017] ISSN 2348 – 8034
DOI- 10.5281/zenodo.835762 Impact Factor- 4.022

Vector Median Filter (VMF)

VMF was proposed to remove salt and pepper noise. It acts in a way that the windows set on each pixel of the image and the value of color components of red, green, and blue in the central pixel of the window are replaced with color components of one of pixels which is in the window. The selected pixel for replacement is the one that has the minimum sum of Euclidean distances compared with other points of the window. It means that the sum of Euclidean distances (Li) from all points in the window is calculated considering the Eq. (2) for all pixels in the window, and the pixel with minimum value is considered as the output of VMF filter and the central pixel is replaced with it.

$$L_i = \sum_{j=1}^{N} \left\| x_i - x_j \right\|_2 \; for\ i = 1, \ldots..N \qquad (5)$$

In the above equation, xi, xj and N stand for the central pixel, existing pixels in the window and the number of pixels which are set to be in the window, respectively.[3]

III. EXPERIMENTAL RESULTS

Experiments were conducted to denoise a MRI image of a neck which is a Original image shown in Fig.2. Speckle and Gaussian noises were considered. The denoised output images for different filters and applying different noise varience is presented the following Figs. The Wiener Filter and different noise varience is presented in Fig.3. The Adaptive Fuzzy Filter and different noise varience is presented in Fig.4. The Vectot Median Filter and different noise varience is presented in Fig.5.

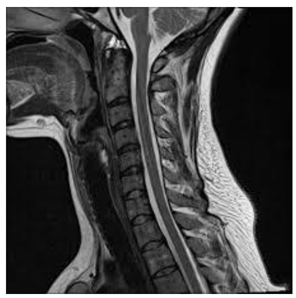


Fig.2.Original Image

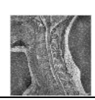
Noise Varience	Speckle		Gaussian	
	Noisy Image	Denoised Image	Noisy Image	Denoised Image
0.01				
0.02				
0.03				

Fig.3.Denoising Using Weiner Filter

[Habiba, 4(7): July 2017]
DOI- 10.5281/zenodo.835762

ISSN 2348 – 8034
Impact Factor- 4.022

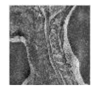
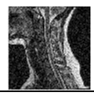
Noise Varience	Speckle		Gaussian	
	Noisy Image	Denoised Image	Noisy Image	Denoised Image
0.01				
0.02				
0.03				

Fig.4.Denoising Using Adaptive Fuzzy Filter

Noise Varience	Speckle		Gaussian	
	Noisy Image	Denoised Image	Noisy Image	Denoised Image
0.01				
0.02				
0.03				

Fig.5.Denoising Using Vector Median Filter

IV. PERFORMANCE ANALYSIS

Performance Metrics

Peak Signal to Noise Ratio(PSNR)

PSNR is the peak signal to noise ratio in decibles(DB).The PSNR is measured in terms of bits per sample or bits per pixel.The image with 8 bits per pixel contains from 0 to 255.The greater PSNR value is, the better the image quality and noise suppression

$$PSNR = 10 \times \log_{10}\left(\frac{peak^2}{MSE}\right) \quad (6)$$

Structural similarity index measure(SSIM)

The structural similarity index is a method for measuring the similarity between two images .The SSIM index is a full reference metric, measuring of image quality based on an initial noise free image as reference. SSIM is designed to improve on traditional methods like peak signal to noise ratio.

$$SSIM(A,B) = \frac{(2\mu_A\mu_B + C_1)(2\sigma_{AB} + C_2)}{(\mu_A^2 + \mu_B^2 + C_1)(\sigma_A^2 + \sigma_B^2 + C_2)} \quad (7)$$

Where µA and µB are the estimated mean intensity along A,B directions and σA and σB are the standard deviation respectively. σAB Can be estimated

$$\sigma_{AB} = \left(\frac{1}{N-1}\sum_{i=1}^{N}(A_i - \mu_A)(B_i - \mu_B)\right) \quad (8)$$

C_1 and C_2 are constants and the values are given as

$$C_1 = (K_1 L)^2$$
$$C_2 = (K_2 L)^2$$

Where K_1, K_2 << 1 is a small constant and L is the dynamic range of the pixel values (255).The resultant SSIM index is a decimal value between -1 and 1, and value 1 is only reachable in the case of two identical sets of images.

Image Quality Index (IQI)

IQI is another important factor to analyse the performance of image denoising in terms of correlation, luminance distortionand contrast distortion. For input image (X) and denoised image (W), the IQI can be defined as:

$$IQI = \frac{4\sigma_{XW}\bar{X}\bar{W}}{(\sigma^2{}_X + \sigma^2{}_W)[(\bar{X})^2 + (\bar{W})^2]} \quad (9)$$

Where,

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i, \bar{W} = \frac{1}{N}\sum_{i-1}^{N} W_i, \sigma^2{}_X = \frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2$$

$$\sigma^2{}_W = \frac{1}{N-1}\sum_{i=1}^{N}(W_i - \bar{W})^2$$

and

$$\sigma_{XW} = \frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})(W_i - \bar{W}) \quad (10)$$

The quality of image index range lies between 1 and -1. The highest value 1 represents an identical value of input image pixel and denoised image pixel. The lowest value -1 shows that the pixels values are uncorrelated.

Performance Evaluation

The performance of the Contourlet transform and different Filtering techniques were studied using the metrics **PSNR, SSIM, IQI** .The first experiment is conducted to estimate the performance of Wiener Filter and different noise varience. Results are shown in Table 1. The second experiment is conducted to estimate the performance of Adaptive Fuzzy Filter and different noise varience. Results are shown in Table 2. The third experiment is conducted to estimate the performance of Vector Median Filter and different noise varience. Results are shown in Table 3.Finally, conclude the performance of best filter and related metrics.

Table i. Wiener filter with metrics

Noise Type	**Noise Varience**	**Metrics**		
		PSNR	**SSIM**	**IQI**
Speckle	0.01	19.0461	0.66852	0.58222
	0.02	18.6907	0.62699	0.54587
	0.03	18.3572	0.59476	0.51785
Gaussian	0.01	17.286	0.37831	0.39049
	0.02	17.338	0.37958	0.39598
	0.03	17.3328	0.37906	0.39759

Table ii. Adaptive fuzzy filter with metrics

Noise Type	Noise Varience	Metrics		
		PSNR	SSIM	IQI
Speckle	0.01	20.0927	0.73605	0.63391
	0.02	19.6537	0.6922	0.59604
	0.03	19.2651	0.65729	0.56477
Gaussian	0.01	17.5653	0.40515	0.4185
	0.02	17.4236	0.40376	0.41823
	0.03	17.2127	0.40188	0.41909

Table iii. Vector median filter with metrics

Noise Type	Noise Varience	Metrics		
		PSNR	SSIM	IQI
Speckle	0.01	17.7502	0.65444	0.58313
	0.02	17.4353	0.612	0.54643
	0.03	17.1825	0.58029	0.51843

Gaussian	0.01	16.2914	0.37721	0.39434
	0.02	16.292	0.37989	0.39829
	0.03	16.2031	0.3805	0.39949

V. Conclusion

In this paper, Contourlet based different filtering techniques are used to improve the quality of the Medical Image. Mainly in the case of presence of Speckle noise and Gaussian noise, filtering is very much required in order to improve the medical image diagnostic examination.Three filters used namely, Wiener filter, Adaptive Fuzzy filter, Vector Median Filter.The denoised image Adaptive Fuzzy Filter gives best results in both noises. We Know three different types of filters are used to remove both noises. Finally,the Adaptive Fuzzy filter gives better results than other filters.

REFERENCES

1. *Manoj Kumar and Manoj Diwakar ”A New Locally Adaptive Patch Variation Based CT Image Denoising” I.J. Image, Graphics and Signal Processing,2016, 1, 43-50.*
2. *Sukhjinder Kaur “Noise Types and Various Removal Techniques” International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)Volume 4, Issue 2, February 2015.*
3. *S. Shyam Prasad and R. Priya ” Image Enhancement with Noise Reduction in Spatial Domain” International Journal of Advanced Research in Computer Science and Software Engineering 5(1),January -2015, pp. 563-566.*
4. *Anisha, S.R PG Scholar and Dr.J. Venugopala Krishnan” Comparison of Various Filters for Noise Removal in MRI Brain Image” International Conference on Futuristic Trends in Computing and Communication (ICFTCC-2015) online at www.internationaljournalssrg.org, ISSN: 2348 –8549.*
5. *Sakthivel K.”Contourlet Based Image Denoising Using New-Threshold Function” International Journal of Innovative Research in Computer and COmmunication Engineering, Vol.2, Special Issue 1, March 2014.*
6. *Bhateja, Vikrant, et al. "A modified speckle suppression algorithm for breast ultrasound images using directional filters."ICT and Critical Infrastructure: Proceedings of the 48th Annual Convention of Computer Society of India-Vol II. Springer International Publishing,2014.*
7. *Rupinderpal Kaur ,Rajneet Kaur “Image Denoising supported wavelet Techniques exploitation Threshold for for Medical photos ”International Journal of computer Trends and Technology (IJCTT),voiume four issue eight aug2013.*
8. *R. Verma and J. Ali “A Comparative Study of Various Types of Image Noise and Efficient Noise Removal Techniques”, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 3, no. 10, (2013) October , ISSN: 2277 128X.*
9. *Miss Monika shukla1, Dr.Soni changlani, ―A Comparative Study of Wavelet and Curvelet Transform for Image Denoising,‖IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p-ISSN: 2278-8735. Volume 7, Issue 4 (Sep. -Oct. 2013), PP 63-68.*
10. *P. Kamboj and V. Rani, “A BRIEF STUDY OF VARIOUS NOISE MODEL AND FILTERING TECHNIQUES”, Journal of Global Research in Computer Science REVIEW ARTICLE Available Online at www.jgrcs.info©, vol. 4, no. 4, (2013) April.*
11. *insufficient Garg” up Segmentation by Denoising Brain imaging photos through Interpolation Median Filter in ADTVFCM” International Journal of computer Trends and Technology-volume4Issue2-2013.*
12. *Fayed, Hassan, Mohamed Rizk, and Ahmed AboulSeoud. "Improved Medical ImageRetrieval using Contourlet Techniques Based Interest Points Detector."Canadian Journal on Image Processing and Computer Vision4.2 (2013).*
13. *Anutam and Rajni, “COMPARATIVE ANALYSIS OF FILTERS AND WAVELET BASED THRESHOLDING METHODS FOR IMAGE DENOISING”, International Journal of Computer Applications (0975 –8887) vol.86, no. 16, (2012) January.*

14. S.Sulochana and R.Vidhya " Image Denoising using Adaptive Thresholding in Framelet Transform Domain" International Journal of Advanced Computer Science and Applications (IJACSA) , Vol. 3, No. 9, 2012.
15. Hiremath, P. S., Prema T. Akkasaligar, and Sharan Badiger. "Removal of Gaussian Noise in Despeckling Medical Ultrasound Images."The International Journal of Computer Science & Applications (TIJCA)1.5 (2012).
16. Burhan Ergen" Signal and Image Denoising exploitation riffle Transform"www.intechopen.com [10] S.Satheesh" medical image denoising exploitation adaptative threshold supported Advanced Computing contourlet transform": a worldwide Journal (ACIJ), Vol.2, No.2, March 2011 .
17. Suresh Kumar, Papendra Kumar, Manoj Gupta, Ashok Kumar Nagawat" Performance Comparisonof Median and Wiener Filter in Image De-noising"International Journal of Computer Applications (0975 – 8887)Volume 12– No.4, November 2010.
18. Hiremath, P. S., Prema T. Akkasaligar, and Sharan Badiger. "Speckle reducing contourlet transform for medical ultrasound images."Int J Compt Inf Engg 4.4 (2010): 284-291.
19. Hossein Rabbani, Wavele-Domain Medical Image Denoising victimisation quantity Laplacian Mixture Model" ieee transactions on medical specialty engineering, vol. 56, no. 12, Dec 2009.
20. B. Zhang and J. P. Allebach, "Adaptive bilateral filter for sharpness enhancement and noise removal," IEEE Trans. Image Process., vol. 17, no. 5, pp. 664–678, May 2008.
21. B. Smolka, "Peer group filter for impulsive noise removal in color images," Lecture Notes in Computer Science (LNCS 5197). Springer-Verlag, 2008, pp. 699-707.
22. Song, Xiao-yang, et al. "Speckle reduction based on contourlet transform using scale adaptive threshold for medical ultrasound image."Journal of Shanghai Jiaotong University (Science)13 (2008): 553-558.
23. H. Hu and G. de Haan, "Trained bilateral filters and applications to coding artifacts reduction,"in Proc. IEEE Int. Conf. Image Processing, 2007, vol. 1, p. 325328.
24. E. D. Gelasca and T. Ebrahimi, "On evaluating metrics for video segmentation algorithms," presented at the 2nd Int. Workshop on Video Processing and Quality Metrics for Consumer Applications, Jan. 2006.
25. R. Lukac, B. Smolka, K. Martin, K. Plataniotis, A. Venetsanopoulos, "Vector filtering for color imaging," IEEE Signal Processing Magazine, Special Issue on Color Image Processing, vol. 22, 2005, pp. 74-86.
26. S. Kim and J. P. Allebach, "Optimal unsharp mask for image sharpening and noise removal," J. Electron. Imag., vol. 15, p. 0230071, 2005.
27. R. Lukac, "Adaptive color image filtering based on center-weighted vector directional filters," Multidimensional Systems and Signal Processing, 2004, vol. 15, pp. 169-196.
28. PU-YIN LIU et al., " Fuzzy techniques in image restoration research-a survey", International Journal of Comp-utational Cognition Volume 2, Number 2, Pages 131–149, June 2004 .
29. Wavelet domain image de-noising by thresholding and Wiener filtering. Kazubek, M. Signal Processing Letters IEEE, Volume: 10, Issue: 11, Nov. 2003 265 Vol.3.
30. Minh ,N."Directional Multiresolution Image Representations,"(Doctoral dissertation of Engineering), Computer Engineering, University of Canberra, Australia, 2002.
31. K. Plataniotis, D. Androutsos, A. Venetsanopoulos, "Adaptive fuzzy systems for multichannel signal processing," Proceedings of the IEEE, 1999, vol. 87, pp. 1601-1622.
32. J. Astola, P. Haavisto, Y. Neuvo "Vector median filters," Proceedings of the IEEE, vol. 78, 1990, pp. 678-689.[33] Govindaraj.v, sengottaiyan.g "Survey of image denoising using different filters".