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Empirical Evaluation of Wavelet & Contourlet Transform for Medical Image Denoising Using Shrinkage Thresholding Techniques

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ABSTRACT: Image denoising is one of the rife task for removal of noise. The occurrence of noise may be taking of images, transfer of images. In medical images the occurrence of noise may extend to false diagnosis. To expel the presence of noise in image the denoising technique is employed. The DWT transform is applied with input images to get the finer details of image. It will preserve the image coefficients without loss of an image quality. Contourlet transform also applied to the image to decompose various direction functionalities of the given input image. It uses Laplacian Pyramid Filter Bank (LPFB) to preserve the edges and line continuity of images. The noises in X-ray image are decimated with the help of thresholding techniques. The noises may be corrupted with Speckle noise and Poisson noises. After the removal of noises, the results of contourlet and DWT are analysed with the performance parameters like PSNR (Peak Signal to Noise Ratio), SSIM (Structural Similarity Index) and IQI (Image Quality Index). From the results it observed that Symlet Provides the best result for DWT and its well suited for Block shrinkage and Contourlet provides the best result for Block and Bayes shrinkage.

KEYWORDS: DWT transform, Contourlet transform, LPBF, Thresholding techniques.

I. INTRODUCTION

Image denoising is the notable task to eliminate noise present in image. The main aim of denoising is to eject the noise without loss of image details and the quality of image. Medical image attempt to expose the internal structure of body as well as diagnosis and treat the disease. X-ray is in the form of electromagnetic radiation. It is used to image inside of visually opaque objects. It acquire high resolution of image.

Noise is a haphazard variation of image, it occurred during the image acquisition. Noise may Additive, Multiplicative.Medical Images is extremely interrupted by Multiplicative noise.Speckles arise from the patterns of constructive and destructive interference from the transducers resulting in bright and dark dots in the image.Poisson noise is a type of electronic noise which may be modelled by poison process. It most frequently observed with small current or low light intensities.

DWT is also Multiresolution technique. And it suitable for non-stationary signals.In DWT decomposition of an image is carried out into the lowest approximation and several details at different scales and in horizontal, vertical and diagonal directions.This multiscale method is well dealtwithdifferent image resolutions.It will uphold the image details without loss of quality.Contourlet transform is employed with the directional filter bank to capture the discontinuities of line and it gives various directional decomposition.It identifies an antistrophic components.

Thresholding is a non-linear technique. It will employ on images to decimate the noise present in image. The decomposition of the image in to the image coefficients, this image coefficient gets processed by using the thresholding for the restoration of noiseless image coefficients.

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II. RELATED WORK

Image Denoising is a central pre-processing step in image processing to eliminate the noise in order to strengthen and recover small details that may be hidden in the data [2].Image noise is the random variation of brightness or colourinformation in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector [7].

Wavelet transform is a mathematical technique that decomposes the signal into series of small basis function called wavelets. It allow the multiresolution analysis of image and is well localized in both time and frequency domain. As a result of wavelet transform the image is decomposed into low frequency and high frequency components. The information content of these sub images that corresponds to Horizontal, Vertical and Diagonal directions implies unique feature of an image[3].

The contourlet transform can effectively overcome the disadvantages of wavelet; contourlet transform is a multi-scale and multi-direction framework of discrete image. In this transform, the multiscale analysis and the multi-direction analysis are separated in a serial way. The Laplacian pyramid (LP) [18] is first used to capture the point discontinuities, then followed by a directional filter bank (DFB) [17] to link point discontinuities into linear structures.

The threshold method, developed by Donoho [15] in 1995, provides a viable treatment option for the wavelet coefficients of nonlinear processing and, consequently, significantly advanced the field of image denoising. Objective quality measures are based on a mathematical comparison of the original and processed or enhanced image and can give an immediate estimate of the Perceptual quality of an image enhancement algorithm[11][12].

III.MOTIVATION AND JUSTIFICATION

Image denoising is a proficiency for removing the noise. The denoising algorithm helpsto exclude the noise without the loss of image features and image quality.It is the process of diminution of the degradedimages which are incurred while the image is being acquired.

The DWT transform is one of the powerful tool for non-stationary signal representation. It is a multiresolution technique and it decomposes the image with the lower and higher coefficients and preserve the properties of an image. It overtook up with the localization and frequency information details. It avoid the block artifacts.Contourlet transform that offers with an eminent degree of directionality. It decomposes the image with filter bank. These filter banks are easily represent the edges and line without discontinuity.Laplacian Pyramid is expended to perceive the line discontinuities. This transform will help to smoothen the geometric structure of images.Motivated by these facts and the results of DWT and contourlet gives better result for thresholding function to eliminate the noises present in image.

IV. ORGANIZATION OF THE PAPER

The paper is formulated as follows. Methodology includes the outline of the work of DWT and Contourlettransforms.Thresholding Shrinkage Functions are presented in Section V. Experimental results are shown in Section VI. Finally Conclusion is shown in Section VII.

V. PROPOSED ALGORITHM

A. Outline of the proposed work

Speckle and Poisson noises are added with input image. Theoutline of the proposed system is presented in Fig1.DWT and Contourlet is used to decompose the noisy images and get the noisy coefficients. These coefficients are denoised with threshold shrinkage function. Inverse transform is applied to get the denoised image

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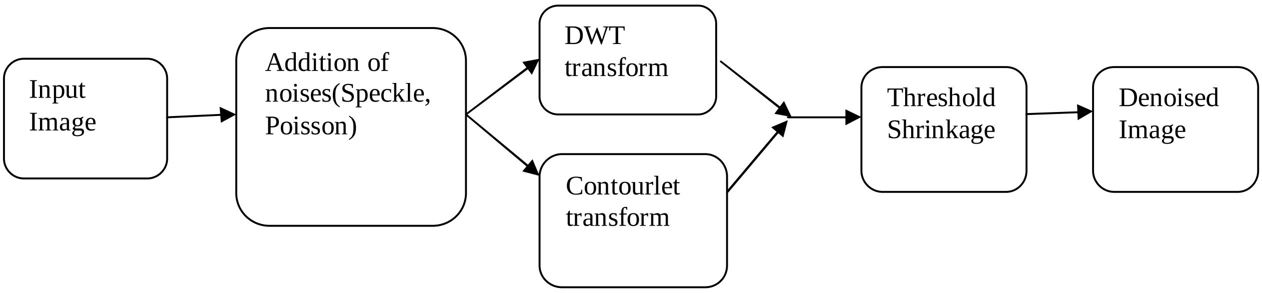

Fig.1 Block Diagram for DWT and Contourlet with Threshold

B.DWT

Wavelet denoising attempts to remove noise which is present in the signal while retaining all the signal characteristics regardless of its frequency contents. The frequency sub-band LH is used to constitute the vertical details of the image, HL contains the horizontal details of the image and the HH sub-band contains the diagonal details of the image. The LL sub-band that is the approximation of the digital image could be further decomposed with the use of discrete wavelet transform to get any level of decomposition of the digital content and it will generate the further four sub-bands. Sub band LL caries approximate element of image, LH contain the vertical element of image, HL contain the horizontal element of image and HH contains diagonal element of image. Thus the information of image is stored in decomposed form in these sub bands[19]. Fig 2 shows the decomposition of image at Level 1.

LL1	HL1
LH1	HH1

Fig.2 Decomposition of image at Level 1

C.Wavelet families

i) Daubechies Wavelets

Ingrid Daubechies invented what are called compactly supported orthonormal wavelets , one of the brightest stars in the world of wavelet research, thus making discrete wavelet analysis practicable [8].

ii) Symlet

The family of Symlet wavelet is short of “symmetrical wavelets”. Symlets are “symmetrical wavelets”. They are designed so that they have the least asymmetry and maximum number of vanishing moments for a given compact support[5].

D. 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 [22].

E. Thresholding Techniques

Thresholding is a technique used for signal and image de-noising. The shrinkage rule defines how we apply the threshold [20] [6]. It is clearly proved that highest PSNR value is achieved at lowest standard deviation and lowest

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PSNR at highest Standard Deviation. Most of the real time and online applications require these types of filters with less execution time.

i) Block Shrink

Block Shrink is a completely data-driven block thresholding approach and is also easy to implement [21]. It can decide the optimal block size and threshold for every wavelet sub band by minimizing Stein's unbiased risk estimate (SURE). The block thresholding simultaneously keeps or kills all the coefficients in groups rather than individually, enjoys a number of advantages over the conventional term-by-term thresholding. The block thresholding increases the estimation precision byutilizing the information about the neighbourwavelet coefficients. The local block thresholding methods all have the fixed block size and threshold and samethresholding rule is applied to all resolution levels regardless of the distribution of the wavelet coefficients [21].

ii) Bayes Shrink

BayesShrink is a sub band adaptive data driven thresholding method. This method assumes that the wavelet coefficients are distributed as a generalized Gaussian distribution in each sub band. Bayes Shrink was proposed by Chang, Yu and Vetterli.The goal of this method is to minimize the Bayesian risk, and hence its name, Bayes Shrink [14]. The Bayes threshold is defined as

$$\lambda = \frac{\sigma^2_{noise}}{\sqrt{\max(\sigma^2_y - \sigma^2_{noise}, 0)}} \qquad (1)$$

This method defines the rules of applying the threshold to the wavelet coefficients. The threshold is compared to all coefficients of the wavelet domain and when the coefficients are less than the threshold value they are assigned zero values, otherwise they are kept unaltered. The reason behind it is that small coefficients are supposed to be not of signal elements and so can be modified to zeroes. The large coefficients are supposed to be of important signal features band. It also finds a threshold which minimizes the Bayesian risk.

$\sigma^2$is the noise variance and σ is the signal variance.

iii) Neigh Shrink

The method Neigh Shrinkthresholds the wavelet coefficients according to the magnitude of the squared sum of all the wavelet coefficients, i.e., the local energy, within the neighbourhoodwindow [4].The neighbourhood window size may be 3×3, 5×5, 7×7, 9×9, etc. But, the authors have already demonstrated through the results that the 3×3 window is the best among all window sizes.

$$T_{ij}=1-\frac{T_u^2}{S_{ij}^2} \qquad (2)$$

where, $T^2{}_u is$ the **universal threshold** and $S^2{}_{ij}$ is the squared sum of all wavelet coefficients in the respective 3×3 window given by:

$$S_{ij}^2 = \sum_{n=j-1}^{j+1} \sum_{m=i-1}^{i+1} Y_{m,n}^2 \qquad (3)$$

Here, + sign at the end of the formula means to keep the positive values while setting it to zero when it is negative.The estimated centre wavelet coefficient $F^{\hat{}}{}_{ij}$is then calculated from its noisy counterpart Y_{ij}as$F^{\wedge}$=$T_{ij}Y_{ij}$.

F. Noise Models

i) Speckle Noise

Speckle is a complex phenomenon, which degrades image quality with a backscattered wave appearance which originates from many microscopic diffused reflections that passing through internal organs and makes it more difficult for the observer to discriminate fine detail of the images in diagnostic examinations [15]. Thus, denoising or reducing the noise from a noisy image has become the predominant step in medical image processing. For the quality and edge preservation of images [13].

$$g(x,y)=f(x,y)*n(x,y) \qquad (4)$$

Where g(x,y) is the result of the original image function f(x,y) corrupted by the multiplicative noise n(x,y).

ii) Poisson Noise

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This noise mainly occurs in medical application like X-ray imaging and Infra-red imaging.[1] A Poisson noise can be stated in terms such that each pixel y of an image f(y) is derived from Poisson distribution function with parameter, c=f(y) Where c is the original image to be drawn.

VI.EXPERIMENTAL RESULTS

Experimental were conducted to denoisean X-Ray image of Chest is shown in Fig 3.Noises are Speckle and Poisson are considered. Two wavelet bases are decomposed with Level1.Different thresholding function were also studied. Contourlet and DWT results of denoised output images of x-ray are shown in Fig 4 and Fig5.

Fig.3 Original Image x-ray

Fig.3 shows the original input X-ray image of chest.

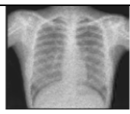
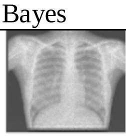
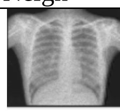
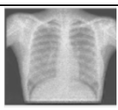
Noise	Speckle Noise			Poisson Noise		
Noisy Image						
Wavelet Type	Threshold type					
	Bayes	Neigh	Block	Bayes	Neigh	Block
DB4						
SYMLET						

Fig.4Denoising using Wavelet bases for x-ray image

Fig.4 shows the Speckle and Poisson noise image and also depicts the denoised X-ray chest image of DWT transform of a wavelet family DB4 and Symlet for the Bayes Shrink, Neigh Shrink and Block Shrink.

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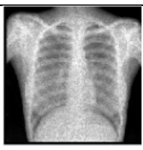
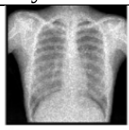
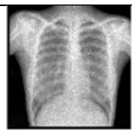
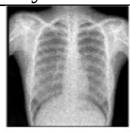
Noise	Speckle Noise			Poisson Noise		
Noisy Image						
Contourlet	Threshold type					
	Bayes	Neigh	Block	Bayes	Neigh	Block
						

Fig.5Denoising using Contourlet x-ray image

Fig.5 shows noise images of speckle noise and Poisson noise and also depicts the denoised X-ray chest image of Contourlet transform for the Bayes Shrink, Neigh Shrink and Block Shrink.

A. **Performance Metrics**

i) Peak Signal to Noise Ratio (PSNR)

It is the ratio between maximum possible power of a signal and the power of corrupting noise thataffects the quality and reliability of its representation. PSNR is calculated as

$$PSNR = 10 Log_{10}\left(\frac{MAX^2}{MSE}\right) \qquad (5)$$

Where MSE is mean square error and MAX is the maximum pixel value of image [9].

ii) Structural Similarity Index (SSIM)

It is a method for measuring the similarity between two images. The SSIM measure the image quality based on an initial distortion-free image as reference.

$$SSIM = \frac{(2\mu_x \mu_y + c_1)(2\sigma_{x,y} c_2)}{(\mu_x^2 + \mu_y^2 + c1)(\sigma_x^2 + \sigma_y^2 + c2)} \qquad (6)$$

μ_x the average of x;

μ_y the average of y;

σx^2 the variance of x;

σy^2 the variance of y;

$C_1 = (k1L)^2$ and $C2 = (k2L)^2$ are two variables to stabilize the division with weak denominator. L the dynamic range of the pixel-values k1 = 0.01 and k2 = 0.03 by default. 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 data [10].

iii) Image Quality Index (IQI)

The Image Quality Index (IQI), Q, is proposed by Wang and Bovik [16] as a product of three different factors: loss of correlation, luminance distortion, and contrast distortion and is defined as

$$Q = \frac{\sigma_{fg}}{\sigma_f \sigma_g} \cdot \frac{2\bar{f}\bar{g}}{\bar{f}^2 + \bar{g}^2} \cdot \frac{2\sigma_f \sigma_g}{\sigma_f^2 + \sigma_g^2} \qquad (7)$$

The first component of eqn. (10) is the correlation coefficient between f and g, which measures the degree of linear correlation between f and g and its dynamic range is [-1,1]. The second component, with a value range of [0,1], measures how close the mean luminance is between f and g. σ_f and σ_g can be viewed as estimate of the contrast of f and

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g, so the third component with a value range of [0,1] measures how similar the contrasts of the images. Thus, Q can be rewritten as

$$Q=\frac{4\sigma_{fg}\bar{f}\bar{g}}{(\sigma_f^2+\sigma_g^2)(\bar{f}^2+\bar{g}^2)} \quad (8)$$

B. Performance Evaluation

The performance of Wavelet bases and Contourlet were evaluated by using PSNR, SSIM, and IQI. Different wavelet bases such as DB4 and SYMLET and Contourlet domain is estimated. Considered all the metrics, it is clearly identified SYMLET performs well in Wavelet bases.In Table 1 Wavelet denoised results are shown and Contourlet denoised results are shown in Table 2.

Table 1 DWT vs Threshold

Wavelet type	**Metrics**	**Speckle Noise**			**Poisson Noise**		
		Threshold Type					
		Bayes	**Neigh**	**Block**	**Bayes**	**Neigh**	**Block**
DB4	**PSNR**	23.4438	23.4554	23.4422	29.4380	29.4275	28.2291
	SSIM	0.8729	0.8731	0.8724	0.7241	0.7125	0.7012
	IQI	0.4387	0.4290	0.4251	0.6285	0.7125	0.7012
SYMLET	**PSNR**	22.0621	22.0613	24.9901	30.2183	30.4275	**30.4889**
	SSIM	0.8677	0.8673	0.8662	0.8932	0.8960	0.8985
	IQI	0.4283	0.4273	0.4212	0.4212	0.7461	0.7489

Table 1 shows the denoisedX-ray chest image with metrics like PSNR, SSIM and IQI for the removal of noises Speckle and Poisson. It shows various thresholding shrinkage like Bayes Shrink, Neigh Shrink and Block shrink of DWT family DB4 and Symlet.

Table 2 Contourlet vs Threshold

	Metrics	**Speckle Noise**			**Poisson Noise**		
		Threshold Type					
		Bayes	**Neigh**	**Block**	**Bayes**	**Neigh**	**Block**
Contourlet	**PSNR**	24.5227	24.5318	24.5519	**26.8889**	26.8809	26.8545
	SSIM	0.54719	0.54736	0.54929	0.63183	0.62975	0.62241
	IQI	0.54787	0.51204	0.54902	0.58797	0.56356	0.54897

Table 2 shows the denoised X-ray chest image with metrics like PSNR, SSIM and IQI for the removal of noises, Speckle and Poisson. It shows various thresholding shrinkage like Bayes Shrink, Neigh Shrink and Block shrink of contourlet transform.

From Table 1 and Table 2 it's observed that the wavelet based techniques and Contourlet based techniques are best suitable for Poisson noise removal. In table 1, SYMLETprovides the better result for Block shrinkage techniques. In Contourlet, it is well suited for Bayes shrink are shown in Table 2.

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VII.CONCLUSION

The DWT and Contourlet transform is compared in this paper. The wavelet and contourlet based noise removal with thresholding extends with high quality and flexibility for the issues of noise in images. The input X-ray images is disseminated with Speckle noise and Poisson noise. The Qualitative measure such as PSNR, SSIM, and UQI are used to estimate the noise removal of images.

From the result it is observed that, Block Shrink is suited for the removal of Poisson noise and Speckle noise in SYMLET of DWT family. In Contourlet transform Speckle noise is better removal of Block Shrink and Poisson noise is work well for the Bayes Shrink.

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BIOGRAPHY

Jannath Firthouse P, received the M.sc degree in Computer Science from MS University in 2015 and B.sc degree in Computer Science from MS University in 2013.She is currently pursuing the M.Phildegree in Computer Science under the guidance of Shajun Nisha. Her Research interest are mainly include domain of Medical Image Denoising

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Shajun Nisha S, Professor and Head of the Department of Computer Science, Sadakathullah Appa College, Tirunelveli. She has completed M.Phil. (Computer Science) and M.Tech. (Computer and Information Technology) in Manonmaniam Sundaranar University, Tirunelveli. She has involved in various academic activities. She has attended so many national and international seminars, conferences and presented numerous research papers. She is a member of ISTE and IEANG and her specialization is Image Mining.