International Journal of Computational Intelligence Research
ISSN 0973-1873 Volume 13, Number 3 (2017), pp. 343-357

http://www.ripublication.com

A new Speckle Noise Reduction Technique to Suppress Speckle in Ultrasound Images

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Abstract

Medical images like ultrasound images are generally corrupted by speckle noise during their acquisition and transmission. The impact of speckle noise reduces the diagnostic value of the medical image modality. Thus, a speckle noise reduction technique is necessary for the suppression of noise and to retain the fine details from the corrupted image. In this article, a new speckle noise reduction technique has been suggested that uses the concept of absolute difference and mean. A kernel size of 5x5 has been used in the proposed filter and experimented using a standard Lena image, 50 ultrasound nerve tumour images and 25 B-mode ultrasound images as test images. These grayscale images used as test images are induced with speckle noise of variance ranging from 0.01 to 0.09. The performance of the proposed filter is compared with Hybrid Modified Median Filter (HMMF), Adaptive Median Filter (AMF) and Non-local Mean and Cellular Automata Filter (NMCA) reported in the literature and measured in terms of performance measures like Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Signal to Noise Ratio (SNR). The result analysis shows the average PSNR as 31.65, MSE as 46.65 and SNR as 70.34 with noise variance 0.01, the average PSNR as 28.10, MSE as 103.72 and SNR as 66.79 with noise variance 0.05 and the average PSNR as 26.23, MSE as

159.33 and SNR as 64.92 with noise variance 0.09 using proposed filter for 50 ultrasound nerve images. The average PSNR as 35.49, MSE as 18.55 and SNR as 78.27 with noise variance 0.01, the average PSNR as 30.51, MSE as 58.80 and SNR as 73.30 with noise variance 0.05 and the average PSNR as 28.37, MSE as 96.34 and SNR as 71.16 for 25 ultrasound B-mode images with noise variance 0.09 of proposed filter.

Keywords: Speckle noise reduction, Ultrasound image, Peak Signal to Noise Ratio, Mean Square Error and Signal to Noise ratio

1. INTRODUCTION

Ultrasound imaging plays a major role in medical imaging because of its non-invasive nature, accuracy, low cost, capability of forming real time imaging, harmless to the human beings and continued improvement in image quality. These medical images are generally corrupted by speckle noise during their acquisition and transmission [1]. This reduces the diagnostic value of the medical image modality and therefore speckle noise reduction becomes an important prerequisite whenever ultrasound imaging is used [2].

Speckle noise is a random multiplicative noise that has a standard deviation which is linearly related to the mean and is often modeled as a multiplicative process [3]. It is responsible for the granularity of coherent imaging systems such as Radar, Laser, Ultrasound and Synthetic Aperture Radar (SAR) [4]. This type of noise decreases the quality of the image by reducing the resolution, contrast of important details in the image. The speckle noise reduction technique helps to suppress the noise and enhance the image. Hence, it becomes an essential preprocessing step for image analysis like segmentation and registration.

De-noising of speckle from ultrasound images still remains a challenge. This article proposes a new speckle noise suppression technique for ultrasound image modality.

2. REVIEW OF LITERATURE

BayesShrink Wavelet Threshold based de-speckle technique has been proposed in [5]. The fourth order PDE based anisotropic diffusion linked with SRAD filter and wavelet based BayesShrink technique has been used as denoising filter to suppress the speckle noise. The performance of the filter has been compared with Lee, Frost, Median, Kaun, Anisotropic Diffusion, SRAD, RHM, Bayes, WEAD existing filter in terms of PSNR.

The experimental results proved that this model produced images which are cleaner, smoother and kept significant details.

Hybrid Modified Median Filter (HMMF) [6] has been introduced for speckle noise reduction in ultrasound image. In this filter, the value of pixel (p) at the center of 3x3 window is altered by the maximum value of modified median(N_4 maximum) pixel value of 8 neighborhood of ‘p’, modified medium(N_D maximum) pixel value of 8 neighborhood of ‘p’ and pixel value of ‘p’. The performance of this filter is compared with median, mean, wiener, frost filters and the result shows better than other filtering techniques.

Extra-Energy Reduction function [7] suppresses the speckle noise in ultrasound images. The logarithmic transformation has been applied to the noisy image and then Gaussian convolution for preprocessing the image. Then the extra-energy reduction analysis has been applied to the image. Extra-energy generally represents noisy signal and destroys the original structure of the image. The extra–energy has been removed from the vector field by triangular shape based on vector triangular formula. Finally, the exponential operator was applied to get the denoised image.

In [8], Intelligent Water Drop (IWD) technique has been used to suppress the speckle noise from the image. This technique depends on soil and velocity. The wavelet transformation is applied on the speckle noise image and their soil and velocity were calculated. The least value of velocity has been replaced by mean value. IWD technique performed noise removal as well as edge preservation better than median and wavelet transform techniques.

An algorithm based on Non-Local Mean and Cellular Automata (NMCA) for the suppression of the speckle noise reduction have been introduced in [9]. The cellular automaton has been exploited to distinguish the noise from the object in the image. The non-local mean concept have been applied assuming that the pixel being considered for denoising have strong connection with the surrounding area in the image. In this algorithm, MLNC (Maximum Likelihood Neighborhood computation) and BEP (Border Edge Preservation) rules were applied to denoise the image.

Adaptive Median Filter (AMF) has been proposed for the speckle noise reduction in [10]. This filter worked in two levels denoted as level A and level B. In level A, A1 is the difference between the median and minimum value and A2 is the difference between the median and maximum value for a adaptive window of size ranging from

3x3 to 7x7. If A1 is greater than zero and A2 is less than zero then go to level B else increase the window size. If the window size has been greater than the maximum window size, then the current central pixel is left unchanged. In level B, B1 is the difference between the center processing pixel and minimum value and B2 is the difference between the center processing pixel and maximum value for a given window. If B1 is greater than zero and B2 is less than zero then center processing pixel is left unchanged. If the above condition is false, then median value has been replaced in the place of the processing pixel. The proposed filter has been experimented using Magnetic Resonance Imaging (MRI), Computerized Tomography (CT), Ultrasound and X-ray medical images. This methodology performs well in all types of medical images.

3. PROPOSED ALGORITHM

The proposed algorithm is based on the research work carried out by Monika Pathak *et al* [9] in the literature for denoising of ultrasound image for speckle noise. The speckle noise induced image is taken as input to the proposed filter. In this algorithm, the 5x5 window has been selected such that P(i,j) is the processing pixel. The 5x5 mask for proposed filter is given in figure 1. The intensity values for the pixel location A1, A2, B1, B2, C1, C2, D1 and D2 are taken into consideration for finding the absolute difference. The mean M1 and M2 are calculated for the pixels which are having the minimum absolute difference between the pixels (A1-A2, B1-B2) and (C1-C2, D1-D2). Then the central processing pixel P(i,j) is replaced by the mean of M1,M2 and P(i,j). The above described process is repeated for the entire image. As a result, the speckle noise suppressed image is obtained. This process is shown in the algorithm.

		D1		
		B1		
C1	A1	P(i,j)	A2	C2
		B2		
		D2		

Figure 1. The 5x5 mask for proposed filter.

3.1. ALGORITHM

Step 1: Read a speckle noisy image.

Step 2: Initialize the window size as 5 (W=5). Assume the center element as processing pixel P(i,j).

Step 3: Calculate the mean (M1) for the pixels which are having the minimum absolute difference between the pixels (A1-A2, B1-B2).

Step 4: Calculate the mean (M2) for the pixels which are having the minimum absolute difference between the pixels (C1-C2, D1-D2).

Step 5: Replace the central pixel P(i,j) with the mean of M1, M2 and P(i,j).

Step 6: Repeat steps from 3 to 5 until all the pixels are processed in the given image.

4. IMPLEMENTATION OF PROPOSED ALGORITHM

The proposed algorithm has been implemented along with existing filter such as HMMF [6], NMCA [9] and AMF [10] using Matlab. The algorithm has been tested using standard Lena image, 50 ultrasound nerve tumour images of size 300x225 from www.ultrasoundcases.info and 25 B-mode ultrasound images of size 538x340 from http://splab.cz/en/download/databaze/ultrasound. The proposed technique has been analyzed based on different speckle noise variance ranging from 0.01 to 0.09 in grayscale JPEG images. Speckle noise has been induced in the original image to produce a noisy image. The noisy image is taken as input to the proposed noise removal filter. The output of the proposed filter gives a denoised image. The flow chart for the proposed filter is shown in figure 2.

5. SIMULATION RESULTS

The performance of the suggested technique is compared with HMMF [6], MNCA [9] and AMF [10] filters using PSNR [11-14, 16], MSE [12-14, 16] and SNR [14, 18-19].

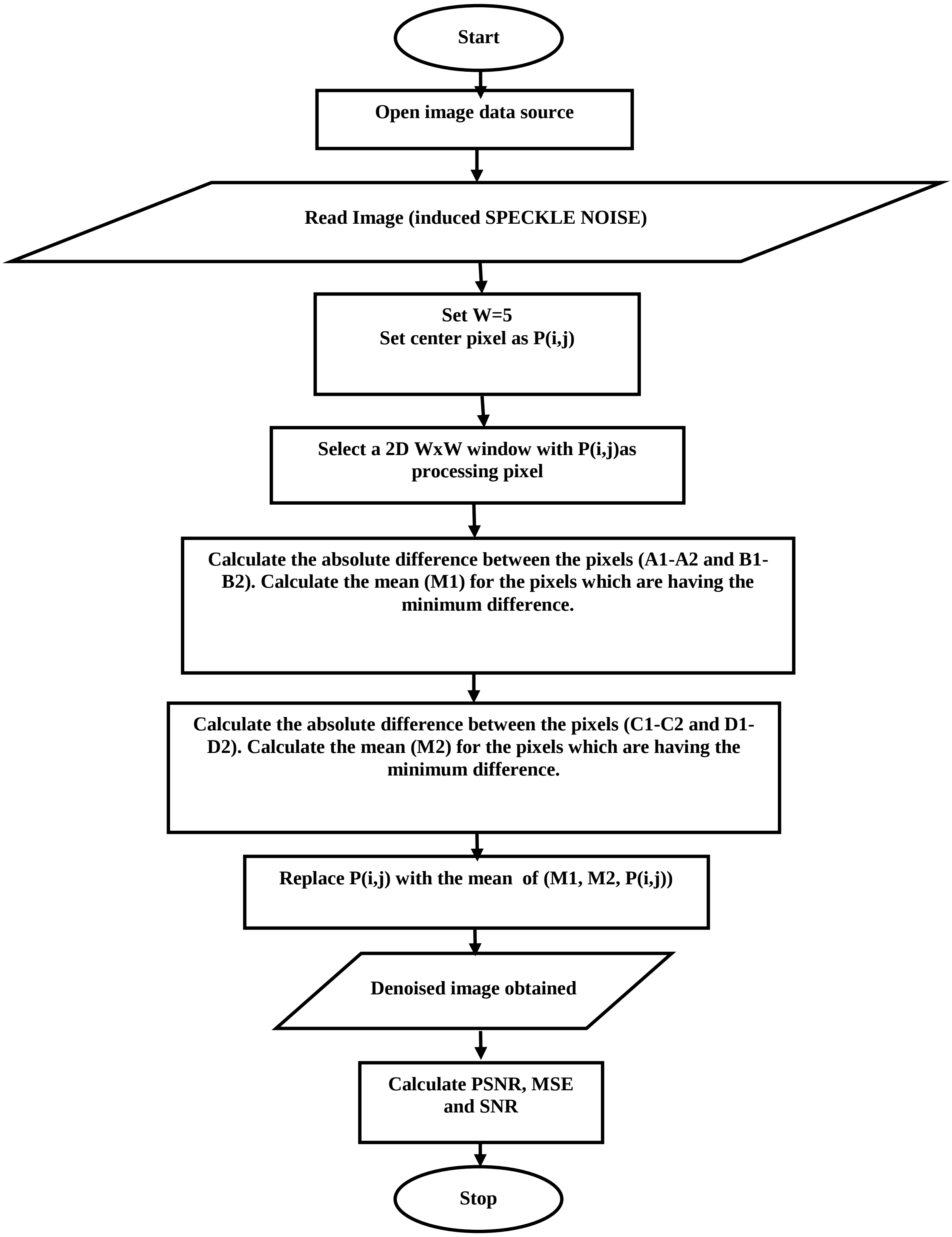


Figure 2. The flow chart for the proposed filter

Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is the most commonly used quality metric. The higher PSNR value represents the better denoising algorithm with high quality of the denoised image. It is the ratio of peak signal in the image to noise and also the difference between images. The PSNR is defined in the equation (1).

$$PSNR = 10log_{10}\frac{255^2}{\text{MSE}} \quad (1)$$

Mean Square Error (MSE)

Mean Square Error (MSE) is the simplest of image quality measurement. MSE is defined as the average of square of the error where error is the difference between desired quantity and estimated quantity. In this, f(x,y) is the original image and $\hat{f}(x,y)$ is the estimated image of size M×N. Lower the MSE value better the denoising algorithm. The MSE is defined in the equation (2).

$$MSE = \frac{1}{\text{M}\times\text{N}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left[f(x,y) - \hat{f}(x,y)\right]^2 \quad (2)$$

Signal to Noise Ratio (SNR)

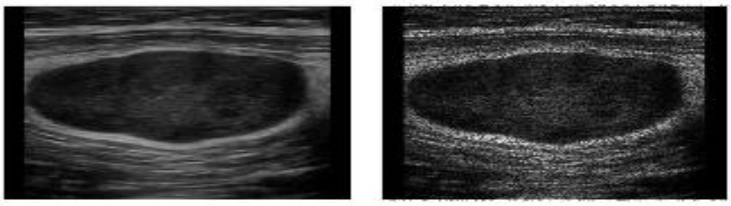
Signal to Noise Ratio (SNR) is the most widely used quality metric that is used to evaluate the multiplicative noise (speckle noise) suppression in coherent imaging. Higher its value indicates the better denoising algorithm. The SNR is defined in the equation (3).

$$SNR = 10log_{10}\frac{\frac{1}{\text{M}\times\text{N}}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}f^2(m,n)}{\text{MSE}} \quad (3)$$

The original Lena image and noise induced image is shown in figure 3. The original ultrasound nerve tumour image and noise induced image is shown in figure 4. The original ultrasound carotid artery image and noise induced image are shown in figure 5. Though the experiment is carried out on variances ranging from 0.01 to 0.09, the output for variance being 0.09 is shown in the figure 6, figure 7 and figure 8 as a sample. The PSNR, MSE and SNR values of the proposed algorithm are compared against the HMMF [6], NMCA [9] and AMF [10] filters using Lena image and the average PSNR, average MSE and average SNR values using 50 ultrasound nerve tumour images and 25 B-mode ultrasound images with speckle noise variance ranging from 0.01 to 0.09 are shown in table 1, table 2 and table 3.

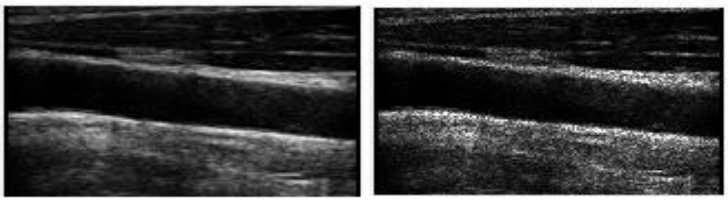
ORIGINAL IMAGE **NOISY IMAGE**

Figure 3. Original Lena image and speckle noisy image of variance 0.09.



ORIGINAL IMAGE **NOISY IMAGE**

Figure 4. Original Ultrasound nerve tumour image and speckle noisy image of variance 0.09.

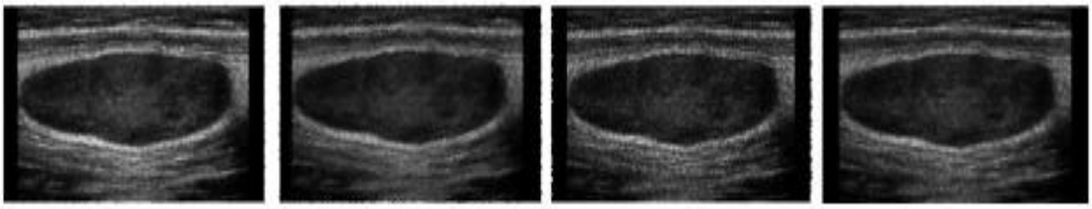


ORIGINAL IMAGE **NOISY IMAGE**

Figure 5. Original Ultrasound carotid artery and speckle noisy image of variance 0.09.

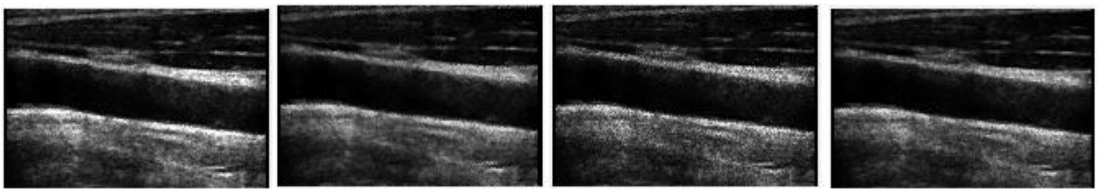
HMMF [6] **NMCA [9]** **AMF [10]** **PROPOSED**

Figure 6. Result of Lena image.



HMMF [6] **NMCA [9]** **AMF [10]** **PROPOSED**

Figure 7. Result of ultrasound nerve tumour image.



HMMF [6] **NMCA [9]** **AMF [10]** **PROPOSED**

Figure 8. Result of B-mode ultrasound carotid artery image.

Table 1. Comparison of average PSNR, MSE, SNR values of LENA image with different noise variance.

Speckle noise density in Variance		**HMMF[6]**	**NMCA[9]**	**AMF[10]**	**PROPOSED**
0.01	**PSNR**	26.54	21.27	27.98	**30.32**
	MSE	143.97	484.64	103.29	**60.32**
	SNR	75.07	69.80	76.51	**78.85**
0.02	**PSNR**	23.75	21.13	25.26	**28.18**
	MSE	273.93	500.92	193.48	**98.80**
	SNR	72.28	69.66	73.79	**76.71**
0.03	**PSNR**	22.07	20.98	23.66	**26.77**
	MSE	402.92	518.22	279.36	**136.49**
	SNR	70.60	69.51	72.19	**75.30**
0.04	**PSNR**	20.94	20.84	22.52	**25.74**
	MSE	523.48	534.74	363.44	**173.15**
	SNR	69.47	69.37	71.05	**74.27**
0.05	**PSNR**	20.08	20.71	21.65	**24.92**
	MSE	638.07	550.93	444.46	**209.10**
	SNR	68.61	69.24	70.18	**73.45**
0.06	**PSNR**	19.35	20.59	20.93	**24.25**
	MSE	753.90	567.51	524.21	**244.06**
	SNR	67.88	69.11	69.46	**72.78**

0.07	**PSNR**	18.79	20.46	20.32	**23.67**
	MSE	857.36	584.28	602.77	**278.82**
	SNR	67.32	68.99	68.85	**72.20**
0.08	**PSNR**	18.28	20.31	19.84	**23.18**
	MSE	965.56	604.24	674.61	**312.33**
	SNR	66.81	68.84	68.36	**71.71**
0.09	**PSNR**	17.83	20.22	19.34	**22.72**
	MSE	1069.66	617.90	756.31	**347.02**
	SNR	66.36	68.74	67.87	**71.25**

Table 2. Comparison of average PSNR, MSE, SNR values of 50 ultrasound nerve tumour images with different noise variance.

Speckle Noise Density in Variance		**HMMF[6]**	**NMCA[9]**	**AMF[10]**	**PROPOSED**
0.01	**PSNR**	30.23	21.14	25.35	**31.65**
	MSE	64.19	526.59	249.91	**46.65**
	SNR	68.92	59.83	64.04	**70.34**
0.02	**PSNR**	28.12	21.06	24.85	**30.43**
	MSE	103.86	536.46	269.78	**61.17**
	SNR	66.81	59.75	63.54	**69.12**
0.03	**PSNR**	26.76	20.98	24.26	**29.50**
	MSE	142.05	545.68	298.99	**75.47**
	SNR	65.45	59.67	62.95	**68.19**
0.04	**PSNR**	25.75	20.90	23.72	**28.74**
	MSE	179.17	554.19	330.15	**89.64**
	SNR	64.44	59.59	62.41	**67.43**
0.05	**PSNR**	24.94	20.83	23.24	**28.10**
	MSE	215.55	562.65	361.06	**103.72**
	SNR	63.63	59.52	61.94	**66.79**
0.06	**PSNR**	24.27	20.76	22.82	**27.55**
	MSE	251.52	571.12	392.35	**117.62**
	SNR	62.96	59.45	61.51	**66.24**
0.07	**PSNR**	23.70	20.69	22.44	**27.07**
	MSE	287.04	579.55	422.56	**131.54**
	SNR	62.39	59.38	61.13	**65.76**
0.08	**PSNR**	23.20	20.62	22.09	**26.63**

	MSE	322.17	587.78	452.76	**145.45**
	SNR	61.89	59.32	60.79	**65.32**
0.09	**PSNR**	22.75	20.56	21.86	**26.23**
	MSE	356.88	596.50	473.26	**159.33**
	SNR	61.44	59.25	60.55	**64.92**

Table 3. Comparison of average PSNR, MSE, SNR values of 25 B-mode ultrasound carotid artery images with different noise variance.

Speckle Noise Density in Variance		**HMMF[6]**	**NMCA[9]**	**AMF[10]**	**PROPOSED**
0.01	**PSNR**	32.42	22.54	32.96	**35.49**
	MSE	37.80	366.26	33.40	**18.55**
	SNR	75.21	65.33	75.75	**78.27**
0.02	**PSNR**	29.90	22.51	30.52	**33.56**
	MSE	67.58	368.83	58.64	**29.03**
	SNR	72.69	65.30	73.31	**76.34**
0.03	**PSNR**	28.37	22.49	29.07	**32.26**
	MSE	96.22	370.68	81.86	**39.18**
	SNR	71.16	65.28	71.86	**75.05**
0.04	**PSNR**	27.26	22.47	28.03	**31.29**
	MSE	124.10	372.54	104.05	**49.10**
	SNR	70.05	65.26	70.82	**74.08**
0.05	**PSNR**	26.40	22.45	27.23	**30.51**
	MSE	151.55	374.33	125.31	**58.80**
	SNR	69.19	65.24	70.02	**73.30**
0.06	**PSNR**	25.69	22.43	26.57	**29.85**
	MSE	178.13	376.13	145.88	**68.41**
	SNR	68.48	65.21	69.36	**72.64**
0.07	**PSNR**	25.10	22.39	26.00	**29.28**
	MSE	204.35	379.07	166.22	**77.94**
	SNR	67.88	65.18	68.79	**72.07**
0.08	**PSNR**	24.58	22.38	25.52	**28.80**
	MSE	230.08	380.20	185.75	**87.16**
	SNR	67.37	65.17	68.31	**71.59**
0.09	**PSNR**	24.13	22.36	25.09	**28.37**
	MSE	255.31	382.14	205.09	**96.34**
	SNR	66.91	65.14	67.88	**71.16**

A plot of PSNR against noise variance for Lena, ultrasound nerve tumour images and ultrasound carotid artery images are shown in figure 9, figure 10 and figure 11 respectively. The suggested speckle noise reduction technique gives a higher PSNR, SNR value and less MSE value for speckle noise with respect to suggested variance (0.01 to 0.09) than the other existing filters. It is very evident that the performance of the proposed algorithm is relatively better than the HMMF, NMCA and AMF filters in the literature on 50 ultrasound nerve tumour images and 25 ultrasound carotid artery images.

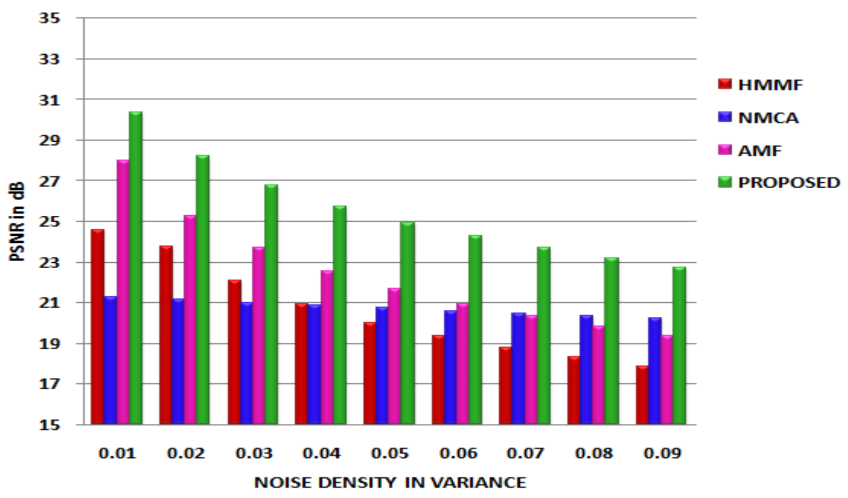


Figure 9. Comparison graph of PSNR at different noise density for Lena image

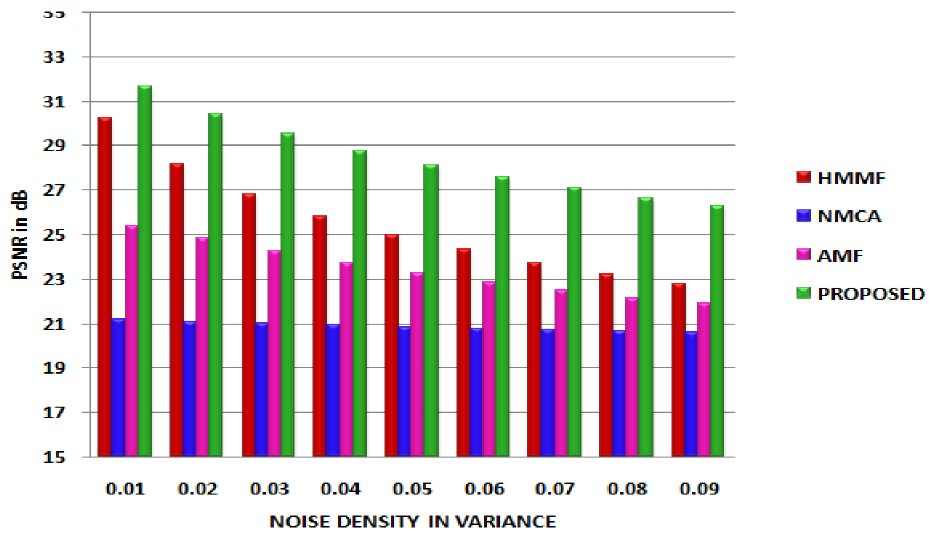


Figure 10. Comparison graph of average PSNR at different noise density for 50 Ultrasound nerve tumour images

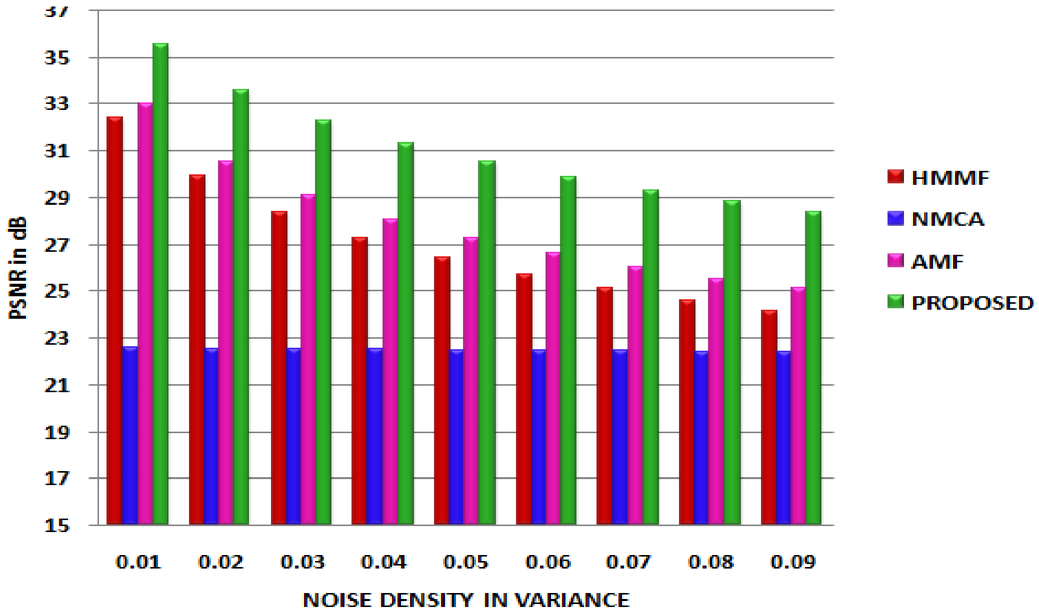


Figure 10. Comparison graph of average PSNR at different noise density for 25 Ultrasound carotid artery images

6. CONCLUSION

In this research work, a new speckle noise suppression technique has been designed. The proposed technique has been tested with Lena image and ultrasound images and its performance has been measured using PSNR, MSE and SNR and compared with the existing filters reported in the literature. The result has been indicated in the above mentioned table. The proposed methodology gives a higher PSNR, SNR value and lower MSE value than the HMMF, NMCA and AMF filters. The above result reveals that the suggested technique superior to the HMMF, NMCA and AMF filters in terms of PSNR, SNR and MSE with respect to ultrasound medical image modality. The proposed filter will be helpful in removing the speckle noise and enhances the image which improves the diagnostic value of the medical image**.** The time taken for execution of HMMF, NMCA, AMF and proposed filter are 17.80, 55.59, 6.39 and 6.23 seconds for ultrasound nerve tumour image and 46.3, 140.50, 16.15 and 16.02 seconds for B-mode ultrasound carotid artery image. Moreover, the time complexity of the proposed algorithm is reasonably better than the other algorithm suggested in the literature. The future work is to develop a novel denoising filter that has the ability to suppress two or more types of noise.

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