DOI: 10.21917/ijivp.2018.0249

DESPECKLEING PROSTATE ULTRASONOGRAMS USING PDE WITH WAVELET

J. Ramesh[1] and R. Manavalan[2]

[1]*Department of Computer Applications, K.S. Rangasamy College of Arts and Science, India*

[2]*Department of Computer Science, Arignar Anna Government Arts College, India*

Abstract:

Prostate cancer is the leading cause of death for men, since the cause of the disease is mysterious and its early detection is also monotonous. Ultrasound (US) is the most popular tool to detect the human organ glands and also used to diagnose the prostate cancer. Speckle noise is an inherent nature of ultrasound images, which degrades the image quality. So far, No specific filter is available to suppress the speckle noise in prostate image. In this paper, a novel despeckling method PDE with Wavelet is presented for prostate US images. The enhancement method is evaluated by using standard measures like Mean Square Error (MSE), Peak Signal Noise Ratio (PSNR) and Edge Preservation Index (EPI). Further, the despeckling approaches' is also evaluated time and space complexity. From the results, it is observed that the filtering method PDE with Wavelet is superior to PDE in terms of denoising and also preserving the information content.

Keywords:

Ultrasound Prostate Image, Partial Differential Equation, Wavelet

1. INTRODUCTION

Ultrasonography is one of the foremost techniques for imaging the internal organs of the human body like breast, kidney, prostate, liver abdomen etc. It is inexpensive, non-invasive, and harmless procedures for diagnosing the organ of the human being. Sonograms generally suffer from speckle noise which degrades image quality and also makes the screening and diagnosis of the disease more complicated. Speckle pattern is always in the form of multiplicative noise that is always directly proportionate to the local grey level in the image. CAD systems yield poor results, since raw US image is affected speckle noise and not suitable for the analysis. To improve the performance, the filtering process is suggested as a preprocessing technique in CAD systems. The filters are intended either in spatial or frequency domain. The various filters in spatial domain such as Mean, Median, Kuan, Wiener, M^2 filter, M^3 filter and Average Median (AVM) filter [1]-[10], [18], [19] are introduced for the removal of speckle noise from ultrasound medical images. These filters remove the speckle noise only some extents and also degrades the image information content while removing the speckle. All these drawbacks provide the opportunity to the researches to find a suitable model for eliminating the speckle from US image and preserving information content. In this research work, a novel approach PDE with Wavelet is introduced as despeckling method for prostate ultrasound images to improve the image quality by removing speckle and preserving information content at maximum level. The outcome of the algorithms is analyzed by using the standard metrics such as Mean Square Error (MSE), Peak-Signal-Noise-Ratio (PSNR) and Edge Preservation Index (EPI) to assess the performance of despeckling methods. Further, the efficiency of the approaches is also evaluated by the time and space complexity. The overview of the proposed model is exhibited in Fig.1.

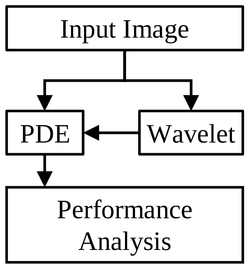


Fig.1. Overview of the Proposed Model

The paper is organized as follows: Section 2 explicate clearly about material and methods used for the removal of speckle noise from US prostate images. In Section 3, the methodology of Partial Differential Equations (PDE) and PDE with Wavelet are expounded clearly for the process of despeckling. The experimental results and their extensive analyses are exhibited in section 4. Finally, this research work is concluded in section 5 with possible future enhancement.

2. MATERIAL AND METHODS

Image enhancement, here, mainly focuses on the poor contrast and speckle of the prostate ultrasound medical images. Speckle noise is a grainy noise that is normally inherent in the US image and debases the image quality. The generalized model of speckle noise is given in [21]. Commonly, the despeckling the image is too hard since dissimilarity resolution and the intensity of the noisy pixel varies with the image intensity [11]. Recently, the various methods are introduced to suppress noise and improve the quality of the US images and the same are briefly reviewed hereunder. Chen and Raheja [22] was proposed speckle noise reduction approach using Wavelet. The method proved its high performance compare to Weiner filter with the threshold scale as 2.5.

Rajan and Kaimal [26] implemented speckle reduction in SAR natural images by using Wavelet Embedded Anisotropic Diffusion (WEAD) and Wavelet Embedded Complex Diffusion (WECD) methods. The method was also compared with other statistical filters. The method yielded maximum PSNR and MSSIM value as 24.16 and 0.6047 respectively than other filtering methods like Frost, Kuan and SRAD.

Michailovich and Tannenbaum [23] have implemented a despeckling method for urinary bladder ultrasound images using wavelets in 2006. The method was compared with hard threshold and soft threshold, in which it earned high SNR values. Yoo et al. [24] proposed the modified Speckle Reducing Anisotropic Diffusion (SRAD) to reduce the speckle noise in US natural image. The method is compared with Median, Kaun, Perona and

SRAD filters. The modified SRAD method yields 3.5% high PSNR values than others.

Sudha et al. [12] proposed Speckle noise reduction in US images by Wavelet Thresholding based on weighted variance. The speckle noise variance ranges from 0.03 to 0.07. The proposed method was compared with various standard speckle filters such as Kaun filter, Frost filter, Weiner filter and Bayes Threshold. The Wavelet based method yielded significantly improved visual quality and also high PSNR values than other filters

Kaur and Singh [25] recommended speckle noise reduction by using Wavelets for natural image. The performance of the method was compared with other statistical method such as Lee, Kaun, Median, SRAD and Weiner filters. Its performance is superior to others.

Karthikeyan et al. [13] recommended speckle reduction in medical US images using Bayesshrink Wavelet Threshold. The results of the model were compared with traditional filters like Median, Lee, Frost and Kaun. The Wavelet based method was tested with PSNR and proved that its performance was better than other filters.

Keikhosravi et al. [14] implemented Fourth-Order Partial Differential Equation for US medical image speckle reduction. The range of speckle noise from 0.05 to 0.3. The efficiencies of the method is compared with Haar wavelet filter and Speckle Reduction with Anisotropic Diffusion (SRAD) filter. The results of the method produced maximum PSNR values and minimum edge preservation compared to wavelet method.

Singhl and Rimpi [28] was recommended Partial Differential Equation (PDE) to remove speckle noise in natural images. The method earned PSNR value as 29.5672, comparatively 5.8% higher than Kuan filter. Nadir Mustafa et al. [27] proposed Wavelet based denoising filters for prostate MRI medical images. The different wavelet threshold techniques such as soft threshold, hard threshold and Bayes threshold are applied and compared at the variance level of 0.04. Bayes threshold method earned low MSE and high PSNR value than other methods.

Rajshree et al. [15] suggested contourlet transform for despeckling noise in fetal US image and MRI image for edge preservation. The method is analyzed with SRAD and curvelet transform. It yielded high PSNR and low MSE values compare to other filters.

Benzarti and Amiri [16] proposed anisotropic diffusion method for speckle noise reduction in US images. The speckle variance used in this method is 0.02. The proposed method yielded an average of 1% high in PSNR and 0.1% low in MSE values than other statistical methods.

Attlas et al. [17] suggested Wavelet Based Techniques for Speckle Noise Reduction in Ultrasound Images. The logarithmic transform is performed to separate the speckle noise from the original image and different wavelet shrinkages such Haar and Daubechies Wavelet are used for noise suppression.

Michahial et al. [29] suggested a filter for despeckling with improved speckle reducing antiscopic diffusion filter for kidney US Images. It earned high PSNR value compare to other statistical filters like Median, Lee, Kuan and Frost. However, all these methods do not guarantee the preservation of edges while removing speckle noise.

In this research work, a novel method, PDE with wavelet is recommended to address the issues in despeckling methods. The detailed explanation of PDE and PDE with wavelet methods for image enhancement is given in section 3.

3. PROPOSED METHOD

Generally, in the US medical image contains noise which degrades the image quality. It is required to design a model for the removal of speckle noise and image enhancement. The various methods are introduced for removal of speckle noise from US image. So far, many filters are introduced in both domain spatial and frequency for prostate US medical image. All these methods are not achieved expected objectives. So, in this work, PDE and PDE with wavelet are introduced for removal of speckle noise. And, the same are briefly discussed in subsequent section 3.1 and 3.2 respectively.

3.1 PARTIAL DIFFERENTIAL EQUATION (PDE)

The traditional image enhancement methods failed to identify and retain the content of information from the low contrast images. To solve this problem, based on nonlinear partial differential equations, an algorithm is designed to enhance the weak images [20]. The algorithm could effectively improve the readability of the image. Besides, PDE method can be applied to real-time processing of video images in the dark. This method enhances not only the dark images and also the bright images, by bring out the hidden details in the dark and bright background. So its application scope is wider, and the visual effect is better. It is simple, fast and effective with real-time dark video image enhancement processing. The core code of this algorithm as follows,

$$t_1 = \exp\left(\left(\frac{-row^2 - col^2}{4}\right) \Big/ e\right)$$

$$t_2 = \exp\left(\frac{\left(\frac{-I.^2 \times c^2}{4}\right) \Big/ e^{-3} \times t_1^2 \times (row + col)^2}{k^2}\right)$$

$$t_3 = I.\times 8 - N - S - W - E - EN - ES - WS - WN$$

$$t_4 = (1 + w) \times t_2 - w$$

If ($I \le e$)

  $h = 0$;

Else if ($I \ge A \times e$)

  $h = 1$;

End

$$I = I + (I.\times(1-h) + h \times I.\times t_3).\times t_4$$

where I is one image to be processed, $w = w$, $k = k$, $e = e_0 \cdot t_1\ t_4$ are the middle of the volumes.

According to t_1, t_2, we get $g(I)$, while from t_3, we get div $\left(\nabla I \div \left|\nabla I\right|\right)$ and $[(1+W)G\left(\left|\nabla G \times \nabla u\right|\right)$ -$w]$ is from t_4. In accordance with the number of iteration, the above steps are carried out in cycles.

3.2 DISCRETE WAVELET TRANSFORM (DWT)

Wavelets are localized waves and a mathematical function, which disintegrate the data or image into approximation coefficients matrix (*cA*) and details coefficients matrices such as horizontal, vertical and diagonal (*cH*, *cV*, *cD*). Therefore, a result of Wavelet is divided into four blocks such as the scaling approximation subband (LL), Horizontal detail subband (LH), Vertical detail subband (HL), and the diagonal detail Subband (HH). A single level 2D wavelet composition is visualized in Fig.2. Finally, it reconstruct the single-level approximation coefficients matrix by using of the above.

LL	**LH**
HL	**HH**

Fig.2. Sub bands of one level 2D Wavelet Transform

3.3 PDE WITH DISCRETE WAVELET TRANSFORM (PDWT)

Generally, Discrete Wavelet Transform (DWT) are considered for US medical images to remove the speckle noise and also preserving the image content of information. It is based on nonlinear partial differential equations with wavelet. In this paper, the PDE is integrated with wavelet to raise a novel approach to enhance the weak goal at maximum for prostate ultrasound medical image enhancement. Usually, PDE with wavelets method embrace the following steps:

Step 1: Read input image (noisy image)

Step 2: Wavelet transformation

Step 3: Modification of coefficients (LL) using partial differential equations,

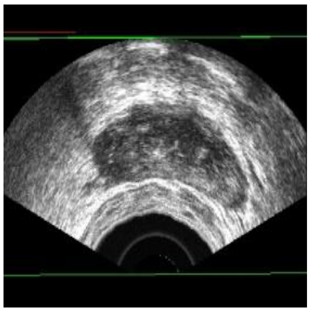
Step 4: Inverse Wavelet

Step 5: Output image (enhance image)

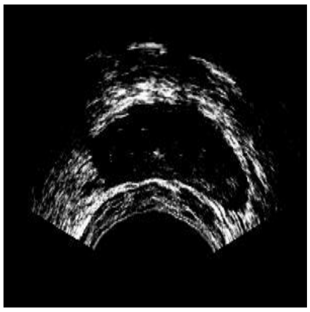
4. EXPERIMENTAL RESULTS AND ANALYSIS

The proposed method is implemented with a set of 50 prostate ultrasound images using Matlab R2015a for removal of speckle noise. During this process, it despeckle and retains the information content of the image. The resultant image of PDE with wavelet are shown in Fig.3.

The performance of proposed method is evaluated for the identification of supremacy in image quality, noise suppression and edge preservation using the standard metrics such as Mean Square Error (MSE), Peak-Signal-Noise-Ratio (PSNR) and Edge Preservation Index (EPI). Further, the proposed model is also evaluated by time and memory complexity. The MSE is the average error rate of the square of difference between the original image and enhanced image where as PSNR is the ratio between the square of the maximum intensity value of an image and the mean squared error of image. Edge Preservation Index (EPI) is used to calculate edge preserving ability of a filter method. The higher value of EPI prove that filter has more ability to preserve edges. The above said parameters are calculated to prove the performance of the filters. The best method is recognized by which method yielding least MSE and highest PSNR and EPI values. The average resultant values of MSE, PSNR and EPI of PDE and PDE with wavelet are shown in the Table.1.



(a) Original Image



(b) Enhanced by PDE

(c) Enhanced by PDE with wavelet

Fig.3. Resultant image of PDE and PDE with wavelet

Table.1. MSE, PSNR and EPI values of PDE and PDE with Wavelet

Methods	MSE	PSNR	EPI
PDE	0.00319	73.26405	0.39295
PDE with Wavelet	0.00228	74.66554	0.789071

Further, the efficiency of proposed method is assessed using complexity of time and space. The average of time and memory taken by the proposed model and PDE method is shown in Table.2.

The Table.1 shows that PDE with wavelet method earned MSE value of 0.00228 which is 0.0091 lesser than the method PDE earned. The PSNR value of PDE is 74.66 where as PDE with wavelet is 73.26 which is 1.4 dB higher than PDE method. The EPI of PDE is 0.3929 and PDE with Wavelet is 0.7890 which is 0.3861 more. This analysis clearly proved that PDE with wavelet outperform well. Further, method is also assessed using complexity. For 50 images, the execution time of proposed method and PDE is 13.46sec and 11.48sec respectively. And memory occupied by PDE and proposed method is 0.79 and 1.21KB respectively. The proposed model takes little high amount of time and memory than PDE model, but it visually shows the better performance than PDE. Finally, it is concluded that PDE with wavelet filtering method is superior for noise suppression and preserving information content of prostate US image.

Table.2. Time and Memory of PDE and PDE with Wavelet

Methods	Time	Memory
PDE	11.48341	0.789063
PDE with Wavelet	13.45745	1.210938

5. CONCLUSIONS

In this paper a novel method - the integration of PDE and Wavelet is introduced for the removal of speckle noise from prostate US images. The standard metrics like Mean Square Error (MSE), Peak Signal Noise Ratio (PSNR), and Edge Preservation Index (EPI) are used to assess the performance of the proposed method. The visual output and results of evaluation metrics clearly showed that supremacy of proposed method over the PDE method. The efficiency of proposed model is also evaluated using time and space complexity. Even though, the proposed method little bit higher memory and time it produces superior results both subjectively and objectively. Further, the proposed research work may be extended to other medical images. Techniques such as Neural Network, Rough Set can be integrated with the proposed method for further improvement in the suppression of speckle noise from prostate ultrasound images.

REFERENCES

[1] M.S. Lee, C.L. Yen and S.K. Ueng, "Speckle Reduction with Edges Preservation for Ultrasound Images: using Function Spaces Approach", *IET Image Processing*, Vol. 6, No. 7, pp. 813-821, 2012.

[2] Jorge Quinones and Flavio Perito, "Reduction of Speckle Noise by using an Adaptive Window", *Revista Ingenierias*, Vol. 11, No. 20, pp. 179-190, 2012.

[3] E. Fabijanska and D. Sankowski, "Noise Adaptive Switching Median-based Filter for Impulse Noise Removal from Extremely Corrupted Images", *IET Image Processing*, Vol. 5, No. 3, pp. 472-483, 2011.

[4] K.Z. Abd-Elmoniem, A.M. Youssef and Y.M. Kadah, "Real-Time Speckle Reduction and Coherence Enhancement in Ultrasound Imaging via Nonlinear Anisotropic Diffusion", *IEEE Transactions on Biomedical Engineering*, Vol. 49, No. 9, pp. 997-1014, 2002.

[5] K. Thangavel, "*Intelligent Computing Models*", Narosa Publishing House, 2009.

[6] Y. Guo, H.D. Cheng, J. Tian and Y. Zhang, "A Novel Approach to Speckle Reduction in Ultrasound Imaging", *Ultrasound in Medicine and Biology*, Vol. 35, No. 4, pp. 628-640, 2009.

[7] Z. Yang, S.P. Sinha, R.C. Booi, M.A. Roubidoux, B. Ma, J.B. Fowlkes, G.L. LeCarpentier and P.L. Carson, "Breast Ultrasound Image Improvement by Pixel Compounding of Compression Sequence", *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency*, Vol. 56, No. 3, pp. 465-473, 2009.

[8] Gajanand Gupta, "Algorithm for Image Processing using Improved Median Filter and Comparison of Mean, Median and Improved Median Filter", *International Journal of Soft Computing and Engineering*, Vol. 1, No. 5, pp. 304-311, 2011.

[9] Azadeh Noori Hoshyar, Adel Al-Jumailya and Afsaneh Noori Hoshyar, "Comparing the Performance of Various Filters on Skin Cancer Images", *Procedia Computer Science*, Vol. 42, pp. 32-37, 2014.

[10] Vikrant Bhateja, Mukul Misra, Shabana Urooj, "Bilateral Despeckling Filter in Homogeneity Domain for Breast Ultrasound Images", *Proceedings of International Conference on Advances in Computing, Communications and Informatics*, pp. 1027-1032, 2014.

[11] P.S. Hiremath, Prema T. Akkasaligar and Sharan Badiger, "Speckle Noise Reduction in Medical Ultrasound Images", *Intechopen*, pp. 200-241, 2013.

[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, pp. 1793-8201, 2009.

[13] K. Karthikeyan et al., "Speckle Noise Reduction of Medical Ultrasound Images using Bayesshrink Wavelet Threshold", *International Journal of Computer Applications*, Vol. 22, No. 9, pp. 8-14, 2011.

[14] Adib Keikhosravi, et al., "Ultrasound Medical Image Speckle Reduction using Fourth-Order Partial Differential Equation", *Proceedings of 7th Iranian Machine Vision and Image Processing*, pp. 208-215, 2011.

[15] A. Rajshree et al., "Comparative Performance Analysis of Speckle Reduction using Curvelet and Contourlet Transform for Medical Images", *Middle-East Journal of Scientific Research*, Vol. 24, No. 1, pp. 88-95, 2016.

[16] Hossein Rabbani, Mansur Vafadust, Purang Abolmaesumi and Saeed Gazor, "Speckle Noise Reduction of Medical Ultrasound Images in Complex Wavelet Domain using Mixture Priors", *IEEE Transactions on Biomedical Engineering*, Vol. 55, No. 9, pp. 2152-2160, 2008.

[17] Nishtha Attlas and Sheifali Gupta, "Wavelet Based Techniques for Speckle Noise Reduction in Ultrasound Images", *International Journal of Engineering Research and Applications*, Vol. 4, No. 2, pp. 508-513, 2014.

[18] E.S. Samundeeswari, P.K. Saranya and R. Manavalan, "M^2 Filter For Speckle Noise Suppression In Breast Ultrasound Images", *ICTACT Journal on Image and Video Processing*, Vol. 6, No. 2, pp. 1137-1144, 2015.

[19] E.S. Samundeeswari, "AVM: A Statistical Filter for Preprocessing B-Mode Breast Ultrasound Images", *International Journal of Informative and Futuristic Research*, Vol. 3, No. 4, pp. 534-561, 2015.

[20] Sathya Subramaniam and Manavalan Radhakrishnan, "Neural Network with Bee Colony Optimization for MRI Brain Cancer Image Classification", *International Arab*

Journal of Information Technology, Vol. 13, pp. 118-124, 2015.

[21] R. Gonzalez, R. Woods and S. Eddins, "*Digital Image Processing using MATLAB*", 2nd Edition, Prentice Hall, 2004.

[22] Yuan Chen and Amar Raheja, "Wavelet Lifting for Speckle Noise Reduction in Ultrasound Images", *Proceedings of IEEE International Conference on Engineering in Medicine and Biology Society*, pp. 3129-3132, 2005.

[23] Oleg V. Michailovich and Allen Tannenbaum, "Despeckling of Medical Ultrasound Images", *IEEE Transactions on Ultraonics, Ferroelectrics and Frequency Control*, Vol. 53, No. 1, pp. 64-78, 2006.

[24] Byeongcheol Yoo and Toshihiro Nishimura, "A Study of Ultrasound Images Enhancement using Adaptive Speckle Reducing Anisotropic Diffusion", *Proceedings of IEEE International Symposium on Industrial Electronics*, pp. 251-256, 2008.

[25] Amandeep Kaur and Karamjeet Singh, "Speckle Noise Reduction using Wavelets", *Proceedings of National Conference on Computational Instrumentation*, pp. 1-3, 2010.

[26] J. Rajan and M.R. Kaimal, "Speckle Reduction in Images with WEAD and WECD", *Proceedings of International Conference on Computer Vision, Graphics and Image Processing*, pp. 514-523, 2006.

[27] Nadir Mustafa et al., "Medical Image De-Noising Schemes using Wavelet Transform with Fixed Form Thresholding", *Proceedings of 11th IEEE International Conference on Wavelet Active Media Technology and Information Processing*, pp. 301-307, 2015.

[28] Ranbir Singh, "Enhanced Speckle Noise Reduction technique based on Wavelets Bayes Thresholding and Anisotropic Filter for Ultrasound Images", *International Journal of Applied Engineering and Technology*, Vol. 4, No. 1, pp 43-49, 2014.

[29] Stafford Michahial and Bindu Thomas, "Comparison of Filters for Despeckle with Improved Speckle Reducing Antiscopic Diffusion Filter for Ultrasound Images", *International Journal of Engineering Research in Electronic and Communication Engineering*, Vol. 3, No. 5, pp. 2394-6849, 2016.