A Review of Overcoming Speckle Noise Challenges in Ultrasound Imaging with Different Wavelet Transformation

Ankita Jagdish Rahate
M.Tech Student Department of Electronics & Telecom Engg
Anjuman College of Engg. & Technology
Nagpur, Maharashtra. India
@gmail.com

Dr. Ruhina Quazi
Professor ,Department of Electronics & Telecom Engg
Anjuman College of Engg. & Technology
Nagpur, Maharashtra. India
@gmail.com

***Abstract*— Ultrasound (US) imaging has been a widely used diagnostic tool in various medical fields for several decades. Known for being cost-effective and non-invasive, this technology stands out among other medical imaging systems. Despite its advantages, interpreting and analyzing ultrasound images poses significant challenges. This is mainly due to the presence of a specific type of noise called "speckle," which is also found in similar imaging technologies such as Synthetic Aperture Radar (SAR) and laser imaging. To address this issue, the first phase introduces the Wavelet Transformation Method (WTM). Additionally, the soft thresholding technique is proposed to enhance image de-noising. By applying the soft-thresholding technique to transform the coefficients, the visual quality of noise-affected images is significantly improved.**

Keywords—— ***Ultrasound Images, Speckle Noise, Median, Wavelets, Image denoising, Soft and hard, thresholding***

I. INTRODUCTION

Noise is a common factor that affects the resolution of images and it causes blurring of fine and sharp details of the images. The occurrence of noises in the images is in general due to the physical nature of the imaging systems. Noises in the images can be broadly categorized into additive noise and multiplicative noise. Additive noises are easy to remove but multiplicative noises are image dependent. They are complex to model and difficult to remove. Speckle is a multiplicative noise found in all coherent imaging systems. Medical ultrasound imaging is also known as Ultrasonography. It is a coherent imaging technique widely used in Medical imaging applications like general abdominal imaging, obstetrics & gynaecology, urology, cardiology, and as a guide in many surgical procedures. Ultrasound waves are transmitted into the region of interest and the echo signals resulting from the scattering and reflection are detected and displayed. The images are generated by the pulse-echo technique with frequencies ranging from 1-20 MHz.

Ultrasonography displays the cross sectional view of the object being scanned. The basic operation is the transmission of high frequency sound waves into the body, followed by reception, processing and parametric display of echoes returning from the organs and tissues within the body. This imaging technique has become popular, as it is portable, and produces images with good resolution without the use of ionizing radiation in a cost effective manner. This is a minimally invasive technique, and is very useful in the diagnosis of obstetrics. It is used to image the internal organs like heart, liver, gallbladder, spleen, kidney and to detect problems with muscles, tendons, ligaments, joints and soft tissue. Since ultrasonic imaging is real time, it demonstrates the movement of internal organs, tissues, and blood flow and heart valve functions. Ultrasound images are used to identify the presence of cysts, tumors, and fluid filled sacs. They are also used to examine the superficial structures in the body. The operating frequencies for typical application of the ultrasound imaging are listed in Table.1.1. High frequency waves cannot penetrate deeply and thus it is used in imaging superficial organs. Low frequency waves penetrate into the body, to image the deeply seated organs. The main limitation of ultrasound imaging system is the presence of speckle noise in the image. Speckle noise is signal dependent noise, that arises due to the interference of transmitted and reflected ultrasound waves in the region of interest. Speckle pattern is a form of multiplicative noise and it depends on the nature of the tissue being imaged, and various imaging parameters.

Table 1.1 Typical application and operating frequency range of an Ultrasound imaging system

S. no	Typical Application	operating frequency range(MHz)
1	Cardiology, Obstetrics, Abdominal imaging	2-5
2	Ophthalmology, Peripheral vascular imaging, Testicular imaging	10-20
3	Intra-arterial imaging	20-50
4	Skin, Cellular imaging	Up to 200

Speckle noise degrades the detecting ability of the target and reduces the contrast and resolution of the ultrasound image. This affects the human ability to identify the difference between a pathological tissue and a normal tissue. the speckle noise reduces the detecting ability of the lesion by a factor of eight. Hence the main objective of this thesis is to address the problem of speckle noise reduction in the Ultrasound images.

II. REVIEW OF LITERATURE

Wu Al-Dhabyani et al. (2020) – Dataset of Breast Ultrasound Images[1]

This study introduces a comprehensive dataset of breast ultrasound images, aimed at advancing research in medical imaging and breast cancer detection. The dataset includes annotated images, providing a valuable resource for developing and evaluating machine learning models. Breast ultrasound imaging is a critical tool for diagnosing breast cancer, especially in dense breast tissues where mammography may be less effective. The dataset is designed to address the lack of publicly available, high-quality ultrasound images for research purposes. It includes images with varying characteristics, such as different levels of noise, contrast, and resolution, making it suitable for testing and benchmarking image processing and analysis algorithms. The authors emphasize the importance of this dataset in facilitating the development of automated diagnostic tools, which can improve the accuracy and efficiency of breast cancer detection. By providing a standardized dataset, this work encourages collaboration and innovation in the field of medical imaging.

Andria et al. (2013) – A Suitable Threshold for Speckle Reduction in Ultrasound Images[2]

This paper addresses the challenge of speckle noise in ultrasound images, which degrades image quality and complicates diagnosis. The authors propose a method to determine an optimal threshold for speckle reduction, balancing noise suppression and detail preservation. Speckle noise is inherent in ultrasound imaging due to the coherent nature of the imaging process. The proposed method uses statistical analysis to identify a threshold that effectively reduces noise while maintaining important image features. The authors validate their approach through experiments on synthetic and real ultrasound images, demonstrating significant improvements in image quality. The method is computationally efficient, making it suitable for real-time applications. This work contributes to the field of medical imaging by providing a practical solution for enhancing ultrasound image quality, which can improve diagnostic accuracy and patient outcomes.

Anwar and Rajamohan (2020) – Improved Image Enhancement Algorithms Based on Switching Median Filtering[3]

This study presents improved image enhancement algorithms using switching median filtering, particularly for low-contrast and noisy images. The authors address the limitations of traditional median filtering, which can blur edges and lose fine details. Their proposed method dynamically switches between different filtering techniques based on local image characteristics, effectively reducing noise while preserving edges and textures. The algorithm is tested on various types of images, including medical ultrasound images, and demonstrates superior performance compared to conventional methods. The authors highlight the importance of adaptive filtering in medical imaging, where preserving diagnostic details is critical. This work provides a robust and efficient solution for enhancing image quality, with potential applications in real-time medical imaging systems.

Baselice et al. (2018) – Enhanced Wiener Filter for Ultrasound Image Restoration[4]

This paper introduces an enhanced Wiener filter for restoring ultrasound images degraded by noise and artifacts. The proposed method improves upon traditional Wiener filtering by incorporating additional constraints to better preserve edges and textures. The authors evaluate their approach on both synthetic and real ultrasound images, showing significant improvements in image quality. The enhanced Wiener filter is particularly effective in reducing speckle noise while maintaining diagnostic details. The authors also discuss the computational efficiency of their method, making it suitable for real-time applications. This work contributes to the field of medical image processing by providing a reliable and efficient tool for ultrasound image restoration, which can enhance diagnostic accuracy and improve patient care.

Bedi and Sunkaria (2022) – Ultrasound Speckle Reduction Using Adaptive Wavelet Thresholding[5]

This study proposes an adaptive wavelet thresholding technique for reducing speckle noise in ultrasound images. The method adapts to local image characteristics, providing effective noise reduction while preserving structural details. The authors compare their approach to existing methods, demonstrating superior performance in terms of noise suppression and detail preservation. The proposed technique is computationally efficient and suitable for real-time applications. The authors highlight the importance of adaptive filtering in medical imaging, where preserving diagnostic details is critical. This work provides a robust and efficient solution for enhancing ultrasound image quality, with potential applications in real-time medical imaging systems.

Bini (2021) – Speckle Reducing Non-Local Variational Framework Based on Maximum Mean Discrepancy[6]

This paper introduces a non-local variational framework for speckle reduction in ultrasound images, based on maximum mean discrepancy. The proposed method effectively reduces noise while maintaining image contrast and texture. The authors validate their approach through experiments on synthetic and real ultrasound images, demonstrating significant improvements in image quality. The method is computationally efficient and suitable for real-time applications. This work contributes to the field of medical image processing by providing a reliable and efficient tool for ultrasound image restoration, which can enhance diagnostic accuracy and improve patient care.

Bini and Bhat (2014) – Despeckling Low SNR, Low Contrast Ultrasound Images via Anisotropic Level Set Diffusion[7]

This study addresses the challenge of despeckling low SNR and low-contrast ultrasound images using anisotropic level set diffusion. The proposed method selectively smooths noise while preserving edges, improving image quality for diagnostic purposes. The authors validate their approach through experiments on synthetic and real ultrasound images, demonstrating significant improvements in image quality. The method is computationally efficient and suitable for real-time applications. This work contributes to the field of medical image processing by providing a reliable and efficient tool for ultrasound image restoration, which can enhance diagnostic accuracy and improve patient care.

Burgos-Artizzu et al. (2020) – Evaluation of Deep Convolutional Neural Networks for Automatic Classification of Maternal Fetal Ultrasound Planes[8]

This paper evaluates the use of deep convolutional neural networks (CNNs) for automatically classifying common maternal-fetal ultrasound planes. The authors demonstrate the potential of CNNs in automating ultrasound image analysis, reducing the workload of clinicians and improving diagnostic accuracy. The study highlights the importance of deep learning in medical imaging, particularly for tasks that require high precision and reliability. The authors validate their approach through experiments on a large dataset of ultrasound images, demonstrating superior performance compared to traditional methods. This work contributes to the field of medical imaging by providing a robust and efficient tool for automating ultrasound image analysis, which can enhance diagnostic accuracy and improve patient care.

Chang et al. (2000) – Adaptive Wavelet Thresholding for Image Denoising and Compression[9]

This study presents an adaptive wavelet thresholding technique for image denoising and compression. The method effectively balances noise reduction and detail preservation, making it suitable for a wide range of applications, including medical imaging. The authors validate their approach through experiments on various types of images, demonstrating superior performance compared to traditional methods. The proposed technique is computationally efficient and suitable for real-time applications. This work contributes to the field of image processing by providing a reliable and efficient tool for image denoising and compression, which can enhance image quality and reduce storage requirements.

Chen et al. (2021) – 3-D Gabor-Based Anisotropic Diffusion for Speckle Noise Suppression in Dynamic Ultrasound Images[10]

This paper proposes a 3D Gabor-based anisotropic diffusion method for suppressing speckle noise in dynamic ultrasound images. The approach adaptively smooths noise while preserving structural details, improving image quality for diagnostic purposes. The authors validate their approach through experiments on synthetic and real ultrasound images, demonstrating significant improvements in image quality. The method is computationally efficient and suitable for real-time applications. This work contributes to the field of medical image processing by providing a reliable and efficient tool for ultrasound image restoration, which can enhance diagnostic accuracy and improve patient care.

Chen and He (2021) – Image Denoising via an Adaptive Weighted Anisotropic Diffusion[11]

This study introduces an adaptive weighted anisotropic diffusion method for image denoising. The technique adaptively smooths noise based on local image characteristics, effectively reducing noise while preserving edges and textures. The authors validate their approach through experiments on various types of images, demonstrating superior performance compared to traditional methods. The proposed technique is computationally efficient and suitable for real-time applications. This work contributes to the field of image processing by providing a robust and efficient solution for image denoising, with potential applications in medical imaging and beyond.

Donoho (1995) – De-Noising by Soft-Thresholding[12]

This foundational paper introduces soft-thresholding for de-noising, a key technique in wavelet-based noise reduction. The method effectively removes noise while preserving important image features, making it suitable for a wide range of applications, including medical imaging. The authors validate their approach through experiments on various types of images, demonstrating superior performance compared to traditional methods. This work has had a significant impact on the field of image processing, providing a reliable and efficient tool for image denoising that continues to be widely used today. [9].

III. METHODOLOGY

The denoising of an image has been one of the most important field in the area of image processing. It is an important and mandatory pre-processing in wide range of image processing applications. Examples are natural image analysis, medical images, radio astronomy etc. (Coifman and Donoho 1995). Each application may be based on its own particular requirements. In other words, noise reduction in natural images must be handled with specific care, since denoising may cause the loss of image fine details like edges, textures etc due to their same high frequency spectrum as per induced noise

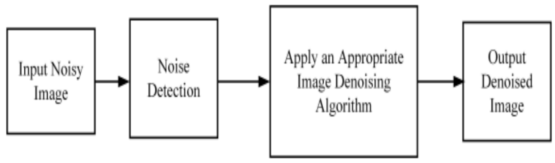

Figure 1: Basic Image Denoising System

The basic image denoising system is given in Figure 1with all the required steps. In its first step, a noisy image with required noise standard deviation is made from the original image and intensity of noise as well as its type is detected next so that an appropriate IDA is applied. Third step can finalized the applicable IDA to reduce the noise with preserving the fine details and color components of the image. After that an output denoised image is reconstructed which is similar to original image. During the image denoising, the main aim is to suppress the noise without paying any attention in preserving the fine details and color components of the image. So in traditional IDAs, the edges may be disturbed due to their over-smoothening (Chen and Lien 2008). The edges of a natural image have a major role in visual perception of the images. So there is a great need to preserve the edges during 2 image denoising The edges have a major role in sharpness of an image. So image denoising with edge preserving continues to attract researcher's attention from other disciplines like image compression, pattern recognition, computer graphics and multimedia, computer vision and psychology.

IV. Conclusion

It is not practically possible to completely remove the noise from an image but a researcher can work towards the better reduction of noise from the noisy image In an efficient image denoising, the fine details and color components must be preserved as much as possible as these are normally disturbed by image denoising process as the frequency spectrum of image fine details and noise are same.

References

[1] Wu Al-Dhabyani, W., Gomaa, M., Khaled, H. and Fahmy, A. (2020) 'Dataset of breast ultrasoundimages', Data in Brief, Vol. 28, p.104863,

[2] Andria, G., Attivissimo, F., Lanzolla, A.M.L. and Savino, M. (2013) 'A suitable threshold forspeckle reduction in ultrasound images', IEEE Transactions on Instrumentation and Measurement, Vol. 62, No. 8, pp.2270–2279,

[3] Anwar, S. and Rajamohan, G. (2020) 'Improved image enhancement algorithms based on theswitching median filtering technique', Arabian Journal for Science and Engineering, Vol. 45,No. 12, pp.11103–11114,

[4] Baselice, F., Ferraioli, G., Ambrosanio, M., Pascazio, V. and Schirinzi, G. (2018) 'EnhancedWiener filter for ultrasound image restoration', Computer Methods and Programs inBiomedicine, Vol. 153, pp.71–81,

[5] Bedi, A.K. and Sunkaria, R.K. (2022) 'Ultrasound speckle reduction using adaptive waveletthresholding', Multidimensional Systems and Signal Processing, Vol. 33, No. 2, pp.275–300,.

[6] Bini, A.A. (2021) 'Speckle reducing non-local variational framework based on maximum meandiscrepancy', Arabian Journal for Science and Engineering, Vol. 46, No. 9, pp.8273–8285

[7] Bini, A.A. and Bhat, M.S. (2014) 'Despeckling low SNR, low contrast ultrasound images viaanisotropic level set diffusion', Multidimensional Systems and Signal Processing, Vol. 25,No. 1, pp.41–65

[8] M.K. Singh et al.Burgos-Artizzu, X.P., Coronado-Gutiérrez, D., Valenzuela-Alcaraz, B., Bonet-Carne, E.,Eixarch, E., Crispi, F. and Gratacós, E. (2020) 'Evaluation of deep convolutional neuralnetworks for automatic classification of common maternal fetal ultrasound planes', ScientificReports, Vol. 10, No. 1, p.10200,

[9] Chang, S.G., Yu, B. and Vetterli, M. (2000) 'Adaptive wavelet thresholding for image denoisingand compression', IEEE Transactions on Image Processing, Vol. 9, No. 9, pp.1532–1546,

[10] Chen, H., Xu, H., Shi, P., Gong, Y., Qiu, Z., Shi, L. and Zhang, Q. (2021) '3-D Gabor-basedanisotropic diffusion for speckle noise suppression in dynamic ultrasound images', Physicaland Engineering Sciences in Medicine, Vol. 44, No. 1, pp.207–219,

[11] .Chen, Y. and He, T. (2021) 'Image denoising via an adaptive weighted anisotropic diffusion',Multidimensional Systems and Signal Processing, Vol. 32, No. 2, pp.651–669

[12] Donoho, D.L. (1995) 'De-noising by soft-thresholding', IEEE Transactions on Information Theory,Vol. 41, No. 3, pp.613–627,

[13] Elyasi, I., Pourmina, M.A. and Moin, M-S. (2016) 'Speckle reduction in breast cancer ultrasoundimages by using homogeneity modified bayes shrink', Measurement, Vol. 91, pp.55-65,

[14] Jing-Yi, L., Hong, L., Dong, Y. and Yan-Sheng, Z. (2016) 'A new wavelet threshold function anddenoising application', Mathematical Problems in Engineering, p.3195492,

[15] Khatkar, K. and Kumar, D. (2015) 'Biomedical image enhancement using wavelets', ProcediaComputer Science, Vol. 48, pp.513–517.

[16] Kokil, P. and Sudharson, S. (2020) 'Despeckling of clinical ultrasound images using deep residuallearning', Computer Methods and Programs in Biomedicine, Vol. 194, p.105477,https://doi.org/https://doi.org/10.1016/j.cmpb.2020.105477.

[17] Luo, L., Zhao, Z., Li, X. and Feng, X. (2019) 'A stochastic image denoising method based onadaptive patch-size', Multidimensional Systems and Signal Processing, Vol. 30, No. 2,pp.705–725

[18] 1.Mittal, A., Moorthy, A.K. and Bovik, A.C. (2012) 'No-reference image quality assessment in thespatial domain', IEEE Transactions on Image Processing, Vol. 21, No. 12, pp.4695–4708

[19] Mittal, A., Soundararajan, R. and Bovik, A.C. (2013) 'Making a 'completely blind' image qualityanalyzer', IEEE Signal Processing Letters, Vol. 20, No. 3, pp.209–212, https://doi.org/10.1109/LSP.2012.2227726.Nabil, T. (2013) 'Iterative projective Gabor method for images filtering', Arabian Journal forScience and Engineering, Vol. 38, No. 10, pp.2745–2753

[20] Priestly Shan, B., Jeba Shiney, O. and Singh, J.A.P. (2021) 'An improved speckle noise reductionscheme using switching and flagging of noisy data for pre-processing of ultrasonograms indetection of down syndrome during first and second trimesters', International Journal ofBiomedical Engineering and Technology, Vol. 37, No. 2, p.105,

[21] An advanced wavelet decomposition based denoising technique 63Randhawa, S.K., Sunkaria, R.K. and Puthooran, E. (2019) 'Despeckling of ultrasound images usingnovel adaptive wavelet thresholding function', Multidimensional Systems and SignalProcessing, Vol. 30, No. 3, pp.1545–1561,

[22] Singh, M.K., Saini, I., Sood, N. and Saini, J. (2021) 'A sub-band anisotropic diffusion technique forde-speckling of ultrasound images of breast cancer', AIJR Proceedings, pp.72–77.

[23] Talbar, S.N., Handique, A., Dutande, P.V., Baid, U., Paul, S. and Mourya, G.K. (2022) 'ModifiedU-Net for fully automatic liver segmentation from abdominal CT-image', International Journal of Biomedical Engineering and Technology, Vol. 40, No. 1, p.1,