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Suppression of Speckle Noise from Ultrasound Medical Images: A Review

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ABSTRACT:

Image de-noising is the pre-processing task which is most important step in image processing. It reduces the impact of the noise signals in the images. Noise signals are unwanted signals which deteriorate the quality of images and suppress the important details in the images. Image processing is one of the important research area in various fields viz. remote sensing, law enforcement, surveillance, astronomy, medical science etc. In the area of medical field; various types of imaging techniques are to be used. Some of the most common techniques are X-ray imagining, computed tomography imaging, ultrasound imaging, magnetic resonance imagining, positron emission tomography imaging etc. These imaging techniques are severely affected by different types of noises; e. g. computed tomography images, ultrasound images and magnetic resonance images are affected by additive white Gaussian noise, speckle noise and rician noise respectively. Manu researchers have developed various techniques to reduces the impact of the noise signals from medical images however no any technique is so efficient enough to reduce the all types of noise signals from all types of images because all the noise signals have different characteristics. Gaussian noise is additive in nature while speckle noise is multiplicative. There are still room to develop more efficient de-noising techniques which have better efficacy than the existing techniques. The man objective of our research is to suppress speckle noise signals from ultrasound images hence to understand the characteristics of speckle noise and existing techniques various research papers have been studied and findings and limitations to be found so that a novel technique can be developed which may give better performance.

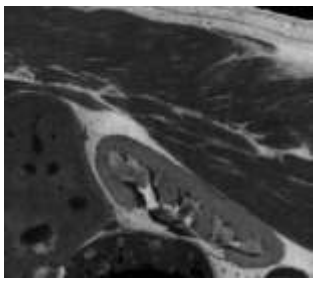
Keywords: Medical Images**,** PSNR**,** SNR, Speckle Noise, SSIM, Ultrasound Images.

1. INTRODUCTION

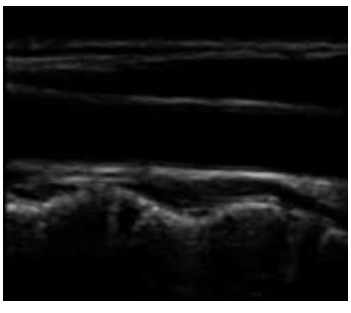
Digital images are the two dimensional information [1]. Let us consider an image is represented by x(i, j) where i and j are spatial coordinates and x is called as the intensity of the gray scale image[2]. If the values of pixel coordinates and amplitude of x both are discrete and finite quantities then image is referred as digital image[3]. Medical imaging is one of the most area for the researchers because it helps the doctors and radiologists to diagnose any abnormalities in the body without any surgical operation [4-7]. There are different types of imaging techniques used for the different purposes in which ultrasound is one of them [8-10].

1.1 Ultrasound images

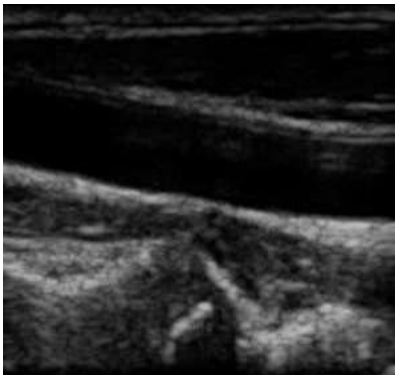
Ultrasound imaging is most popular technique which is used to examine soft tissues in the human body[11]. If there is any problem in some organs viz. stomach, pancreases, liver, kidney, intestines, spleen, urine bladder etc. [12] then doctor refers the patients to the radiologist so that ultrasound images can be obtained[13-15]. Below is the illustration of some ultrasound images.



(a)



(b)



(c) (d)

Fig. 1 ultrasound images

1.2 Noise in Ultrasound Images

Noise in an image may be either additive or multiplicative. Ultrasound images are affected by speckle noise which is the example of multiplication noise[16]. Let us consider the original image is $x(i, j)$ in which noise introduced is $n(i, j)$ as a result noisy image is obtained which is denoted by $y(i, j)$. *Since*, speckle noise is an example of multiplicative noise then,

$$y(i, j) = x(i, j) \times n(i, j) \quad \ldots(1.1)$$

The above two operations is done at pixel level.

Speckle noise introduces in ultrasound image and reduces the quality of image due to which human interpretation and accuracy of clinical diagnosis are affected[17]. Thus speckle noise must be reduced to preserve the texture and edge information of the ultrasound images. Many researchers developed various techniques to reduce the effect of speckle noise from the ultrasound images but no technique suppress the speckle noise completely[18]. Hence there is still scope to develop or modify the existing techniques so that speckle noise can be suppress to acceptable extent and useful information can be retained to avoid any false interpretation done by doctors or radiologists[5-7].

2.LITERATURE REVIEW

To understand the procedure of de-speckling; it is desire to review the existing techniques. Various research papers have been studied in which some of the good researches have been discussed. This literature review illustrates the findings and limitations of that research so that gap analysis can be done.

Yu et al. (2021) implemented two-step filtering technique which is used to decrease the effect of speckle noise from the OCT images. This technique is a combination of Non-Local Means (NLM) filtration and wavelet based thresholding technique. NLM is used to preserve detailed of the images while wavelet based adaptive thresholding is used for noise reduction. Results exhibits better performance of the proposed technique in terms of PSNR and SSIM. This technique also improves the visual quality of the image along with the preservation of details which are very useful information for the diagnosis purpose. This hybrid technique is one of the best example of hybridization of spatial domain and spectral domain filters which enhances OCT image processing[1].

Sang et al. (2020) proposed a noise suppression technique which is used to reduce speckle noise from OCT images. It uses Dual-Density Dual-Tree Complex Wavelet Transform (DD-DTCWT). This technique enhances the quality of image by improving shift invariance and directional selectivity; due to which structures details are preserved. The proposed technique performs better than the traditional wavelet techniques. It preserves edge information, visual quality and other minute details which makes it suitable for high precision OCT images[2].

Chen et al. (2024) implemented a technique which is based on a semi-supervised deep learning method for de-speckling of the OCT images. It combines UNet and Swin-Uformer architectures. UNet is used to capture spatial features and Swin-Uformer is used to bring transformer based global context understanding. The result depicts the better response over traditional techniques as well as fully superviseIt also demonstrates better noise suppression while retaining the structural detail of the images. This technique is the best example of hybrid deep learning models which is used for the enhancement of medical images[3].

Sivaanpu et al. (2024) implemented a hybrid CNN Transformer network which is applied on the ultrasound images for the reduction of speckle noise.This model is used to combine local feature extraction capabilities of Convolutional Neural Networks (CNNs) global context modeling strength of Transformers. This hybridized technique not only suppresses the speckle noise but it preserves the fine structures of medical images. Results depict the improved performance over the traditional filtration technique in terms of diagnostic quality. This technique is suitable for not only ultrasound images but for OCT and similar modalities[4].

Duarte-Salazar et al. (2020) provided an overview of de-speckling techniques which suppresses speckle noise from US images. This paper focuses on the impact of metrological evaluation which is used for various applications in the field of biomedical areas. In this paper; traditional techniques viz. anisotropic diffusion filters and median filter; wavelet based techniques and machine learning techniques have been discussed. This work emphasises the trade-off between noise suppression and preservation of structural details. It also highlights the need of methods for the maintenance of diagnostic accuracy. This extended survey provides a reference for the selection of de-speckling techniques used for clinical and research purposes in the field of image processing[5].

Lee et al. (2022) a new approaches for de-speckling the US medical images which is based on a deep content-aware image prior (DCIP) technique. The main aim of this technique is to improve breast tumor segmentation. This technique utilizes deep learning for learing the image prior which can distinguish between important structures of images and noise signals. As a result; this technique suppresses the noise signals precisely without losing critical tumor boundaries. Result shows that the proposed technique is better than the conventional and other deep learning techniques in terms of enhanced segmentation accuracy[6].

Sikhakhane et al. (2024) overviewed various de-speckling techniques and machine learning algorithms used to suppress speckle noise from US images. This survey compares conventional techniques like Lee filter, Frost filter and median filter with machine learning based approaches. The comparison is done of the basis of capability of noise reduction, computational efficiency and edge preservation. From the results it is clear that machine learning based deep learning outperformed various conventional methods in terms of visual quality and other quantitative metrics. This work can be used as a guide to select effective technique for the medical image denoising[7].

Lan and Zhang (2020) described a real time speckle noise reduction technique which is based on a Residual UNet enhanced with a mixed-attention mechanism. This technique is the integration of spatial and spectral domain. It can suppress speckle noise effectively while preserves feature of US images. Its computational efficiency is very high which is shown by the results. It outperforms almost all traditional and many deep learning techniques. It provides better and fast de-noising for the clinical US imaging[8].

From the above survey it is clear that there are many techniques which outperform traditional methods but there is still room to get better results qualitatively and quantitatively.

3. METHODOLOGY

After extensive survey; it is clear that almost all the techniques follow the simple methodology as discussed below:

- Collection of database which are the set of speckle noise free ultrasound images.
- Select any one ultrasound image from the database.
- Add some amount of speckle noise to get noisy image.
- Apply de-noising technique to get de-noised image.
- To know the efficacy of applied method, calculate some performance evaluation parameters viz. PSNR, SNR, SSIM etc.
- Repeat the procedure for other images from the database with different amount of noise signals.

Fig. 2 illustrates the flow diagram for the de-noising technique.

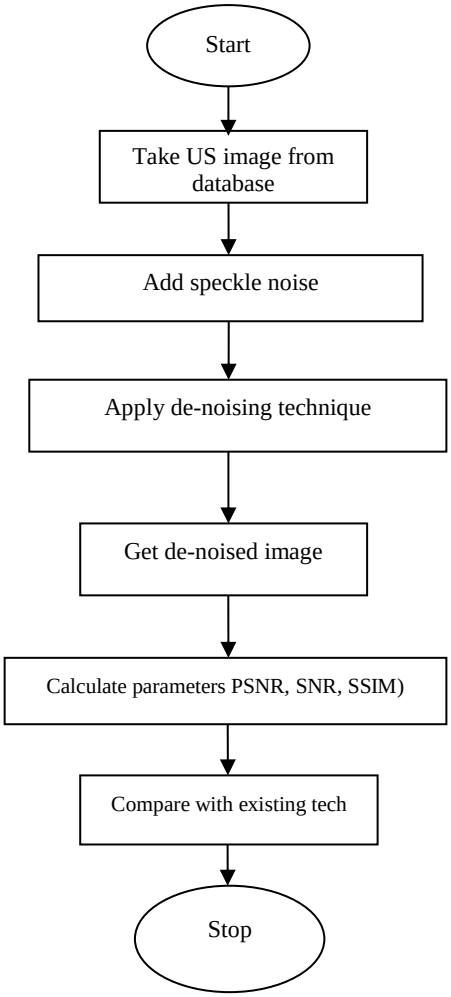


Fig. 2 flow diagram of speckle noise suppression from US images

4. CONCLUSION

From the above discussion it is clear that ultrasound images are severely affected by speckle noise which hampers the image quality and suppresses the details. These details are very important to for the diagnosis purpose hence the main goal of the filtration is not only suppression of speckle noise but retain the fine details also. Researchers have implemented many techniques which efficiently suppress the noise signals and retain the details but there are still hope to improve the image quality. This survey gives much information about the characteristics of spackle noise and ultrasound images which may help to implement a novel technique or improvement the efficacy of the existing techniques. After the extensive survey of related literatures it may be said that; there are still many research gap to suppress the effect of speckle noise. In future new techniques may be developed which can give better results quantitatively and qualitatively. In other words we have to improve the results of the de-noising techniques in terms of PSNR, SNR and SSIM. There are many scopes to improve the efficacy of existing techniques by changing their parameters.

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