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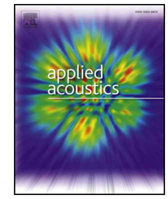

An extensive review on Despeckling of medical ultrasound images using various transformation techniques

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ABSTRACT

In recent years, the ultrasound imaging plays a major role in the medical field. It is the diagnostic imaging technique in which the diagnosis has become more complex due to the presence of speckle noise in the image. This speckle noise significantly reduces the image clarity through the diminution of details of the image like edge details, contrast reduction, and resolution problems. Several types of research have been investigated to reduce the speckle noise. This paper reviews the state-of-the-art of transformation techniques for reducing the speckle noise from medical ultrasound images by considering the challenges on compressing the medical imaging to deduce extraneous information using the non-subsampled contourlet transform.

1. Introduction

The speckle is the rough and unavoidable attribute of ultrasonic images; it upsets the diagnosis ability of the medical images. In general, the speckle noise created due to traveling path difference of the coherent acoustic waves which introduces the interference [1]. The reduction of this noise is elementary while analyzing the ultrasound images for disease characterization. Ultrasound imaging has multiple advantages such as non-obtrusiveness, non-ionizing radiation and effective in cost. With these pros, it is most suitable for diagnosis of thyroid disease in contrast to computed tomography, X-ray, and magnetic resonance imaging. However, the speckle is the main drawback in the medical ultrasonography which reduces the quality of the image. The presence of noise not only affects the observer to analyze and diagnose the image but also difficult for extracting and recognizing the features. Hence, a preprocessing step that is speckle filtering is very critical one (see Fig. 1).

The diagnosis utilizing the computer systems and also the preprocessing methodologies are severely degraded in its performance because of the speckle patterns. It not only deteriorates the resolution and contrast of the ultrasound images but also targets detection process. Hence, the speckle suppression is a prerequisite procedure to enhance the quality of the image with accuracy for diagnosis. Some of the techniques utilized in the speckle reduction are expressed as follows.

The frequency compounding and post processing are the two individual methodologies commonly utilized to reduce the speckle in ultrasound images. The resolution enhancement compression method had addressed the issue of visibility and resolution of the ultrasound image [2]. The spatial and frequency compounding techniques were proved for improving the signal to noise ratio [3]. Whereas improving the measuring frequency range of ultrasonic waves the resolution of the ultrasound image is increased [4]. Adaptive speckle reduction was inherently known as a signal processing algorithm. It was utilized to identify and eliminate the dominated speckle in the ultrasound image [5]. By using the processing of complementary hulling technique, the geometric filter is utilized to reduce the speckle noise [6]. The speckle contrast reduction in phased array ultrasonic images was done through the frequency compounding method [7]. The digital signal processing based Fourier transform was applied to deduct the speckle content in digital holograms [8].

In target detection, the number of methods was suggested before the arrival of the CLEAN algorithm with CFAR (Constant False Rate Alarm) processing. Among which one of the methods compare the statistics of neighboring regions in the image [9]. The solutions were described to this problem are neural networks [10] and Markov random models [11,12]. The major motive of the CLEAN & CFAR combination is to reduce the human interaction in the target detection process. Also, the mentioned algorithm was developed through the threshold value, and it may be subjective. Therefore the CFAR defines the threshold as a false alarm value.

The speckle noise reduction in some specific applications which needs segmentation, region-based detection and classification are processed through the synthetic aperture radar (SAR) community filters. The filters named Lee, Kuan, Frost and Gamma MAP filters are getting much attention in the previously mentioned applications [13]. The preprocessing consists of two steps.

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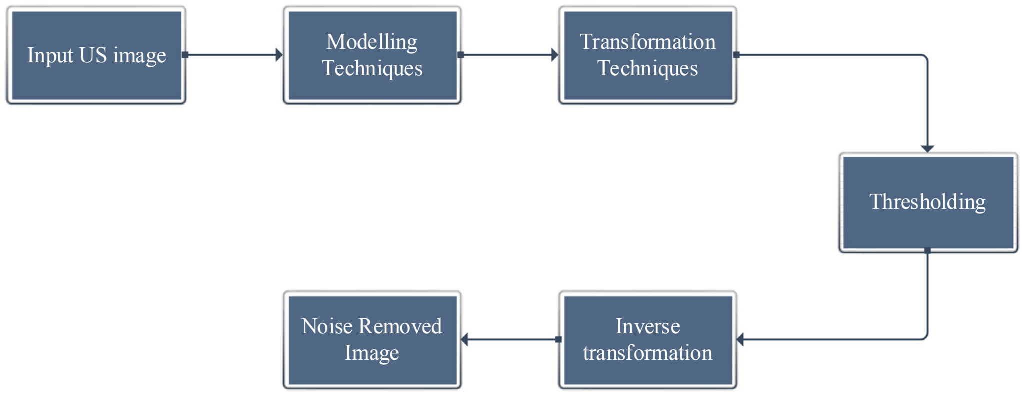

Fig. 1. Representation of De-speckling in US images.

Table 1
Acronyms of different techniques.

SRAD	Speckle reducing anisotropic diffusion
MAP	Maximum a Posteriori
GLD	Generalized Laplacian Distribution
NMWD	Nonlinear Multiscale Wavelet Diffusion
R-ML filtering	Rayleigh-Maximum-Likelihood Filtering
LPND	Laplacian Pyramid-based Nonlinear Diffusion
GOSF	General Order Statistics Filter
FC and REC	Frequency Compounding and Resolution Enhancement Compression
OBNLM	Optimized Bayesian Nonlocal Means Filter
DTCWT	Dual-Tree Complex Wavelet Transform
2D-GARCH CG	Two-Dimensional Generalized Autoregressive Conditional Heteroscedastic Generalized Gaussian
NSST	Non-Subsampled Shearlet Transform
HRGMF	Homogeneous Region Growing Mean Filter
GND	Generalized Nakagami Distribution
DTD	Discrete Topological Derivative
WR-NLM	Weight Refining Nonlocal Means Filter
SBF-DVW	Squeeze Box Filter-Descriptive Visual Words
MSE	Mean Square Error
SNR	Signal to Noise Ratio
SSIM	Structural Similarity Index
PSNR	Peak Signal to Noise Ratio

- For de-correlating, the image samples the radio frequency (RF) image is subjected to a spectrum equalization procedure.
- The log-transformed envelope image departed through a nonlinear outlier-shrinkage system, for suppressing the noise segment of the log-transformed image [14].

The denoising of US (Ultrasound) images is a difficult due to the precise texture of the mentioned images [15]. By enhancing the signal-to-noise ratio with the conservation of the edges and lines in the image the speckle is reduced appropriately [16]. The original noise affected images or more preferred in the medical field than the noise-removed images. Because the smoothening of images done via the filters which sometimes destroy the relevant information of the analysis. Thus, it is necessary to progress noise filters which can preserve the features that are of importance to the physician [17].

In this paper, a total of 10 despeckle filters were evaluated based on local statistics, median filtering, Statistic Kuan Filter, Kalman filter, Homomorphic Filtering, Nonlinear Coherence Diffusion, Anisotropic Diffusion, Wavelet Filtering, Weiner Filter and Frost Filter. Also, the transformation techniques have discussed with the concentration of reducing the speckle from the ultrasound images. The major contribution of this review is analyzing multiple speckle reduction techniques with their pros and cons and selecting the ideal technique from that with future extension (see Table 1).

This paper is systematized as follows: In Section 2, Section 3, and Section 4 it presents a brief review of literature about the de-speckling of medical ultrasound images, De-speckling utilizing non-subsampled contourlet transform, Analysis of Despeckle filters respectively. The experimental validation of the reviewed paper regarding performance analysis is given in Section 5. Furthermore, in Section 6, Section 7 and Section 8 it includes the performance analysis, findings from the survey and conclusion of this documentation respectively.

2. De-speckling of medical ultrasound images

The preprocessing step of de-speckling is held by the process of registration and segmentation of ultrasound images in the medical field. In the human body, the organs and soft tissues can be easily viewed by the technique of ultrasonography due to its characteristics of convenient, shrink, non-ionizing radiation respectively [18]. The scheme of de-speckling or speckle reduction is the crucial one to deny the quality of the image without the corruption of its features [13]. The medical ultrasound images can be de-specked by several methods. The noise sources are degraded to show the picture of medicinal with the lost data in the framework of conventional ultrasound imaging [1].

The wavelet domain with coding scheme of adaptive sub-band is considered for de-speckling [19]. This scheme provides the property of sparsity and multi resolution to suppress the ultrasound speckles and enhances the edge, and it is used to check the performance through the preservation of edge indices [20]. The noise will be created from the overlapping of echoes which will be scaled down from the indices of zero to maximum associated with the interference. The linear filters are used to improve the quality of image through the reduction of noise from the picture [14]. Due to the presence of this noise sources, the efficiency will be reduced, so it is considered as a major source in the image of ultrasound without the degradation of image features [21].

The transducer elements of frequency and geometry in imaging parameters decide the pattern of speckles where the tissues will be taken for the image [22]. The filtered images are required to find out the disease through the way of filtering methods, and transformation in the field of medicine, as well as the noise affected images, suggest some useful information to diagnose the problem [23,24]. During the removal of interference, the pattern from the image gives high contrast. The quality of analysis will degrade during the speckle suppression to improve this by accurate region of interest and reliability [25,26].

The method of log transformation is used in wavelet-based de-speckling in which the conversion process takes place; as a result of this, the additive white noise will be obtained. Then the function of exponential was used to restore the de-speckled image [27]. In US images the speckle reduction and edge preservation is not so important factor, but it is very useful to enhance the characteristics of the model of the image, laser of optical, and SAR (synthetic radar aperture) [28]. After the filtering technique, the temporal averaging also developed to avoid speckles, and it leads blurred image due to this the data will be lost