ABSTRACT

Digital images are used in applications ranging from photography, printing, medical and remote sensing for transmitting visual information in the modern era. Ultrasound (US) has been the most widely used medical imaging modality due to its non-invasiveness, cost effectiveness and real time imaging ability. But its usage is limited due to the introduction of speckle. Speckle is a granular pattern introduced due to the interference of echoes, which are reflected from the tiny tissues, in a constructive or destructive manner. The presence of speckle noise is found to reduce the accuracy of abnormality detection. So, speckle removal is an essential pre-processing step. However, it is more important to ensure that during the process of speckle reduction the essential image details are not removed. Hence there is a continuing need for research on the design of noise removal filters with edge preservation in image processing applications.

Recently, wavelets find their application in several image processing tasks. Wavelet based denoising research focuses on developing new thresholding functions and determining new adaptive thresholds. Several thresholding functions were introduced in the past two decades and are still being expanded to get a better approximation between original and reconstructed coefficients. Also there are only a few methods for modifying the coefficients below the threshold. Adaptive threshold determination techniques based on context selection have been studied by many researchers. But the methods are either computationally complex or require manual parameter selection. The intra and inter-scale correlation that exist among the subband coefficients are used in several ways to enhance the ability of the denoising filters. However, their utilization in estimating the local statistics and in threshold determination is still a growing approach. Also most of the

existing filters produce a smoothed output with less preservation of important image details. Hence there is a lot of scope for further investigations and development of a simple and an efficient wavelet based adaptive filter with a good feature preserving ability.

In this research work, an Enhanced Adaptive Wavelet Filter (EAWF) and Shift Invariant Improved Adaptive Filter (SIIAWF) are investigated for modifying the coefficients above threshold. An Inter-scale Threshold based Wavelet Filter (ISTWF) is discussed for modifying the coefficients below threshold. Finally, a new Fusion based Wavelet Filter (FBWF) is developed for further improving the ultrasound image quality.

EAWF utilizes an inter-scale dependency based homogeneity measure for estimating the signal variance, to determine an adaptive threshold. The resulting performance is better compared to the existing approaches. SIIAWF comprises two frameworks, namely SIIAWF^{1} and SIIAWF^{2}. SIIAWF^{1} proposes a low complexity intrascale measure based variance estimation technique for adaptive threshold determination. It employs a new and improved adaptive threshold function, which reduces the fixed bias of the soft thresholding approach to a greater extent, so that the denoised coefficients better approximate the original coefficients resulting in improved edge preserving ability. SIIAWF^{2} works in two stages. In the first stage, a combined intra and inter-scale measure based variance estimate is employed for adaptive threshold determination. In the second stage, the denoised coefficients are further subjected to thresholding, based on a change in error measure. A new thresholding function is proposed to further reduce the noise, utilizing the change in error measure. Hence SIIAWF shows an improved performance both interms of noise removal and in edge preservation.

ISTWF proposes a new exponential thresholding function to reduce the small magnitude coefficients gradually to zero, in order to reduce the impulsive nature of soft thresholding approach. In wavelet decomposition, fine details are seen as small magnitude coefficients at finer scales. So, to retain these small magnitude coefficients an inter-scale adaptive threshold is proposed utilizing the parent-child relationship of the adjacent scale coefficients. The resulting filter exhibits improved edge preservation along with good noise removal ability.

Finally, a fusion based approach is presented for further improving the quality of US images. The outputs of SIIAWF and ISTWF are combined employing a two stage fusion scheme. The first stage performs an inter-scale activity based fusion followed by a new intra-scale weighted activity based fusion of the two images in the second stage. The weight measure employed improves the edge preserving ability of the filter. The resulting output shows a superior image quality with improved edge preservation.

The performance analysis of the proposed techniques is carried out through various simulations with synthetic phantom and clinical ultrasound images. The results show that they outperform the benchmark soft thresholding algorithm in terms of peak signal to noise ratio by 14.8%, structural similarity index measure by 4.22%, equivalent number of looks by 17.65% and edge preservation index by 49.39% on an average. Moreover, visual quality of the proposed filters is found to be superior to the existing filters.