RESEARCH ARTICLE OPEN ACCESS

Wavelet Based Techniques for Speckle Noise Reduction in Ultrasound Images

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Abstract
De-noising plays a very important role in the field of the biomedical image pre-processing. It is often done before the image data is to be analyzed. This paper presents a review of various techniques for reduction of speckle noise in ultrasound images. Speckle Noise is one of the most prominent noises seen in the ultrasound images and corrupts the visual quality of the image for further processing being multiplicative in nature. This paper demonstrates wavelet based techniques for improving visual image quality in ultrasound images and denoising. With the help of variable window technique and region based processing, discrete wavelet transform technique provided better noise rejection in ultrasound images by removing the speckle noise.
Index Terms— De-noising, Speckle Noise, Ultrasonic Imaging, Wavelet transform.

I. INTRODUCTION

Speckle noise is multiplicative type whereas other noises like Gaussian noise are additive type. It is difficult to remove multiplicative noise from images. We have presented various techniques for removing speckle noise from images and image enhancement by thresholding using various spatial domain filters and Wavelet analysis on the corrupted images have been discussed. Latest domain in the field of Image denoising and compression is using wavelet analysis. Multiresolutional image analysis using wavelets is the latest modification in the field of image enhancement and denoising. Wavelet analysis represents the next logical step: a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. Speckle Noise is the high frequency content in the ultrasound images and can be easily removed using wavelet based thresholding technique.

Biomedical images are generally corrupted by Speckle noise and Gaussian noise. Speckle noise is multiplicative type whereas other noises are additive type and it is difficult to remove multiplicative noise from images. Speckle noise is high frequency content in ultrasound images and can be easily removed using wavelet based Thresholding technique. In medical imaging, such as ultrasound images, image is generated with the help of ultrasonogram, but the basic problem in ultrasound images is speckle noise gets introduced in it. Speckle noise becomes a dominating factor in degrading the image visual quality and perception in many other images. Noise is introduced at all stages of image acquisition. There could be noises due to loss of proper contact or air gap between the transducer probe and body or noise could be introduced during the beam forming process and also during the signal processing stage. Even during scan conversion, there could be loss of information due to interpolation.

De-noising plays a very important role in the field of the medical image pre-processing. It is often done before the image data is to be analyzed. Denoising is mainly used to remove the noise that is present and retains the significant information, regardless of the frequency contents of the signal. It is entirely different content and retains low frequency content. De-noising has to be performed to recover the useful information.

II. IMAGE ENHANCEMENT IN BIONICS

The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide `better' input for other automated image processing techniques.
Image enhancement techniques can be divided into two broad categories:
1. Spatial domain methods, which operate directly on pixels, and
2. Frequency domain methods, which operate on the Fourier transform of an image.
When image enhancement techniques are used as pre-processing tools for other image processing techniques, then quantitative measures can determine which techniques are most appropriate.

Ultrasound imaging plays an important role in medical diagnosis. It is non-invasive, non-expansive, fast, forming real time imaging. But it suffers from a problem that is speckle noise that degrades image quality [1]. Speckle noise is a multiplicative noise. It is a random mottling of dark and bright spots appear in image which effect diagnosis [2]. But it is difficult to remove speckle noise because removing speckle may also remove important information useful in diagnosis [3].

Figure 1: Ultrasound Image corrupted by speckle noise

So, we analyze various techniques among these wavelet transform provide superior results along with filtering technique.

In the process of image denoising using wavelet based transform technique, two-dimensional (2-D) images are transformed from the spatial domain to the frequency domain. An effective transform will concentrate useful information into a few of the low-frequency transform coefficients. An HVS is more sensitive to energy with low spatial frequency than with high spatial frequency.

III. PROBLEM FORMULATION

Matlab software is used to implement the design. DWT will be applied to construct the detail and approximation coefficents and after multilevel decomposition and filtering, reconstruction image will be created using reconstruction coefficents. This research is different from the related literature because in previous techniques results of speckle noise reduction in ultrasound images have been presented using **Median** and **Weiner** filter alone and now we are enhancing the results by combining **Median** and **Weiner** filtering using **DWT** technique. Quantitative analysis would be performed by checking attained Peak Signal to Noise Ratio (PSNR) and Mean Square Error estimation of the denoised image. A comparative analysis of different wavelet families will be performed.

IV. LITERATURE REVIEW

Digital image acquisition and processing techniques play an important role in current day medical diagnosis. Images of living objects are taken using different modalities like X-ray, Ultrasound, Computed Tomography (CT), Medical Resonance Imaging (MRI) etc. [1] highlights the importance of applying advanced digital image processing techniques for improving the quality by removing noise components present in the acquired image to have a better diagnosis. [1] also shows a survey on different techniques used in ultrasound image denoising. [2] has presented the work on use of wiener filtering in wavelet domain with soft thresholding as a comprehensive technique. Also, [2] compares the efficiency of wavelet based thresholding (Visushrink, Bayesshrink and Sureshrink) technique in despeckling the medical Ultrasound images with five other classical speckle reduction filters. The performance of these filters is determined using the statistical quantity measures such as Peak-Signal-to-Noise ratio (PSNR) and Root Mean Square Error (RMSE). Based on the statistical measures and visual quality of Ultrasound B-scan images the wiener filtering with Bayes shrink thresholding technique in the wavelet domain performed well over the other filter techniques. [3] has presented different filtration techniques (wiener and median) and a proposed novel technique that extends the existing technique by improving the threshold function parameter K which produces results that are based on different noise levels. A signal to mean square error as a measure of the quality of denoising was preferred.

V. RESEARCH METHODOLOGY

A. Steps to be followed

Research methodology will be done by the following steps:

1. Input Image (Noisy)
2. Wavelet transform
3. Threshold selection
4. Image decomposition
5. Filtering
6. Image reconstruction using IDWT
7. Computation of qualitative and Quantitative parameters:

B. Algorithm To Be Followed

Study Of **DWT** And **Multilevel Decomposition**

Perform **WEINER** Filtering On Ultrasound Images And apply **DWT** Approach

Calculation Of **Parameters** Of Various Wavelet Families For **WEINER** Filtering Using Matlab

↓

Perform **MEDIAN** Filtering On Ultrasound Images And apply **DWT** Approach

Calculation Of **Parameters** Of Various Wavelet Families For **WEINER** Filtering Using Matlab

↓

Perform **MEDIAN** as well as **WEINER** Filtering Both on ultrasound Images and apply **DWT** Approach

Calculation Of **Parameters** Of Various Wavelet Families For WEINER Filtering As Well As For MEDIAN Filtering Using Matlab

↓

Comparison Of Parameters Of Various Wavelet Families For **MEDIAN** Filtering only then for **WEINER** Filtering only Then For **BOTH** Median Filtering As Well As For Weiner Filtering

VI. DIFFERENT TECHNIQUES FOR IMAGE DENOISING

Various techniques for Image enhancement include Fourier Transform, but it involves only frequency domain analysis but no information in time domain. Then the detailed analysis for both time and frequency domain was introduced in a block by block processing technique, Discrete Cosine transform that had the disadvantage of fixed window size. This was the major problem in previous techniques explained below. This problem was overcome in discrete wavelet transform.

The detailed description of these techniques have been explained below:

A. Discrete Cosine Transform

The discrete cosine transform (DCT) helps separate the image into parts (or spectral sub-bands) of differing importance (with respect to the image's visual quality). The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain (Fig 2)

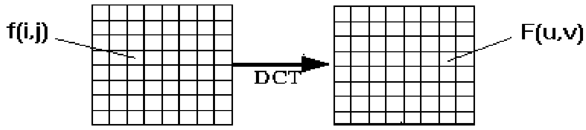

Figure 2: DCT Block Processing

A **discrete cosine transform** (**DCT**) expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. DCTs are important to numerous applications in science and engineering, from lossy compression of audio (e.g. MP3) and images (e.g. JPEG) (where small high-frequency components can be discarded), to spectral for the numerical solution of partial differential equations. The use of cosine rather than sine functions is critical in these applications: for compression, it turns out that cosine functions are much more efficient (as described below, fewer are needed to approximate a typical signal), whereas for differential equations the cosines express a particular choice of boundary conditions.

In particular, a DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), where in some variants the input and/or output data are shifted by half a sample. There are eight standard DCT variants, of which four are common.

The most common variant of discrete cosine transform is the type-II DCT, which is often called simply "the DCT"; its inverse, the type-III DCT, is correspondingly often called simply "the inverse DCT" or "the IDCT". Two related transforms are the discrete sine transforms (DST), which is equivalent to a DFT of real and *odd* functions, and the modified discrete cosine transforms (MDCT), which is based on a DCT of *overlapping* data.

B. Discrete Wavelet Transform

Wavelet analysis represents the next logical step: a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information.

Figure 3: Wavelet Transform on a signal

Wavelet Transform in contrast with the

time-based, frequency-based, and STFT views of a signal:

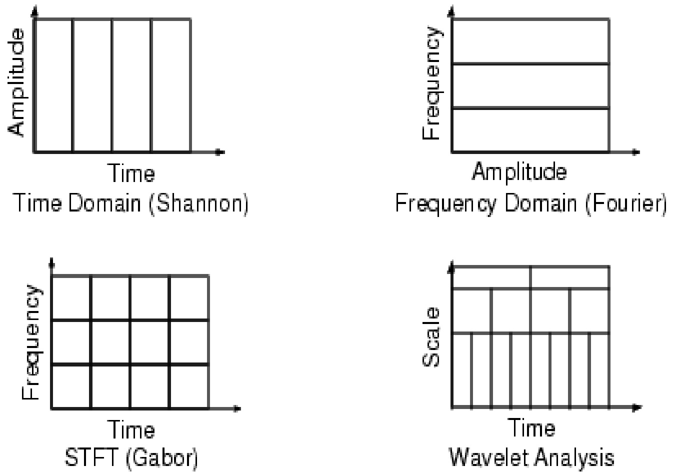

Figure 4: Comparison of Various Transform Techniques

The discrete wavelet transform (DWT) refers to wavelet transforms for which the wavelets are discretely sampled. A transform which localizes a function both in space and scaling and has some desirable properties compared to the Fourier transform. The transform is based on a wavelet matrix, which can be computed more quickly than the analogous Fourier matrix.

Previous techniques of thresholding includes filtering in spatial domain, however, in wavelets, the complete analysis is shifted from spatial domain to frequency domain having both time –scale aspects. Wavelet transform (WT) represents an image as a sum of wavelet functions (wavelets) with different locations and scales. Any decomposition of an image into wavelets involves a pair of waveforms: one to represent the high frequencies corresponding to the detailed parts of an image (wavelet function ψ) and one for the low frequencies or smooth parts of an image (scaling function Ø). The Discrete wavelet transform (DWT) has gained wide popularity due to its excellent decorrelation property, many modern image and video compression systems embody the DWT as the transform stage . It is widely recognized that the 9/7 filters are among the best filters for DWT-based image compression. In fact, the JPEG2000 image coding standard employs the 9/7 filters as the default wavelet filters for lossy compression and 5/3 filters for lossless compression. The performance of a hardware implementation of the 9/7 filter bank (FB) depends on the accuracy with which filter coefficients are represented. Lossless image compression techniques find applications in fields such as medical imaging, preservation of artwork, remote sensing etc [4] . Day-by- day Discrete Wavelet Transform (DWT) is becoming more and more popular for digital image compression. The process of row-wise convolution will divide the given image into two parts with the number of rows in each part equal to half that of the image. This matrix is again subjected to a recursive line-based convolution, but this time column-wise. The result will DWT coefficients corresponding to the image, with the approximation coefficient occupying the top-left quarter of the matrix, horizontal coefficients occupying the bottom-left quarter of the matrix, vertical coefficients occupying the top-right quarter of the matrix and the diagonal coefficients occupying the bottom-right quarter of the matrix[3] .

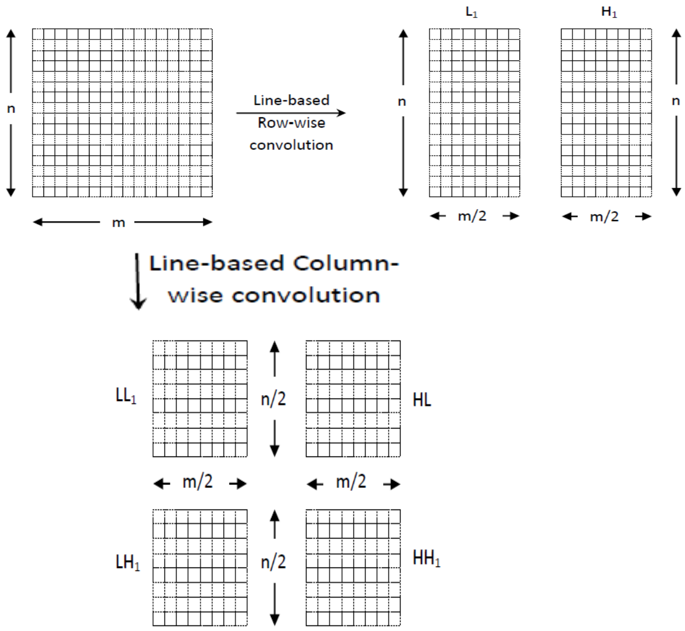

Figure 5: Line based Architecture for DWT

Speckle noise is a high-frequency component of the image and appears in wavelet coefficients. One widespread method exploited for speckle reduction is wavelet thresholding procedure. The basic Procedure for all thresholding method is as follows:

- Calculate the DWT of the image.
- Threshold the wavelet coefficients. (Threshold may be universal or sub band adaptive)
- Compute the IDWT to get the denoised estimate.
- There are two thresholding functions frequently used, i.e. a hard threshold, a soft threshold. The hard-thresholding is described as

$$\square 1\ (w) = wI\ (|w| > T)$$

Where w is a wavelet coefficient, T is the threshold. The Soft-thresholding function is described as

$$\square 2\ (w) = (w - \mathrm{sgn}(w)\, T)\ I\ (|w| > T)$$

Where sgn(x) is the sign function of x. The soft-thresholding rule is chosen over hard-thresholding, As for as speckle (multiplicative nature) removal is concerned a preprocessing step consisting of a logarithmic transform is performed to separate the noise from the original image. Then different wavelet shrinkage approaches are employed. The different methods of wavelet threshold denoising differ only in the selection of the threshold.

VII. WAVELET FAMILIES

Several families of wavelets that have proven to be especially useful are included in the wavelet toolbox. The details of these wavelet Families have been shown below:

A. Haar Wavelets

Haar wavelet is the first and simplest. Haar wavelet is discontinuous, and resembles a step function. It represents the same wavelet as Daubechies db1.

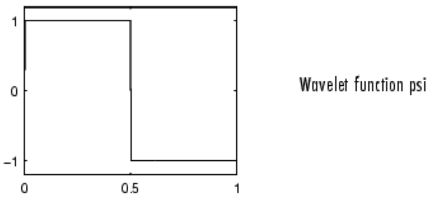

Figure 6: Haar Wavelet Function Waveform

B. Daubechies Wavelet

Ingrid Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthonormal wavelets -- thus making discrete wavelet analysis practicable.

The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet. The db1 wavelet, as mentioned above, is the same as Haar wavelet. Here is the wavelet functions psi of the next nine members of the family:

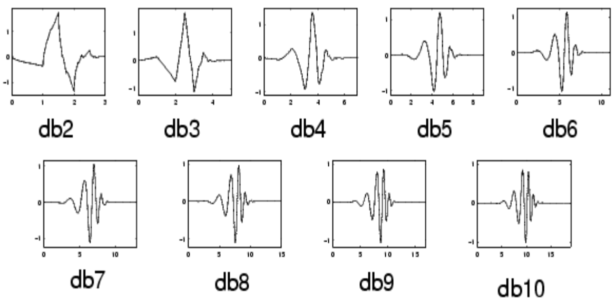

Figure 7: DB Wavelet Function Waveforms

VIII. WAVELET DECOMPOSISTION

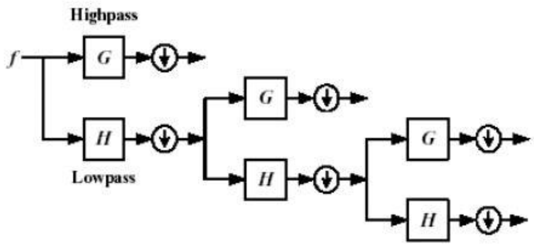

Figure 8: Multilevel Decomposition using low pass and high pass filters for image compression using wavelets

Algorithm follows a quantization approach that divides the input image in 4 filter coefficients as shown below, and then performs further quantization on the lower order filter or window of the previous step. This quantization depends upon the decomposition levels and maximum numbers of decomposition levels to be entered are 3 for DWT.

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