Remove the Noise from Medical Images Using Discrete Wavelet Transform

Rupinderpal Kaur*,Rajneet Kaur**
*(Mtech Student,Department of CSE,SGGSW University,Fatehgarh Sahib,INDIA)
**(Assistant Professor,Department of CSE,SGGSW University,Fatehgarh Sahib,INDIA)

ABSTRACT
The quality of medical image is degraded by many sources of noise such as imperfect instruments, interference from natural phenomena, data acquisition and transmission errors. In MRI images, the image is degraded mainly by Gaussian noise and Salt and Pepper noise respectively. Suppressing noise from medical image is still a challenging problem for the medical researchers and practitioners. There are lots of denoising techniques have been developed over a period. Wavelet gaining popularity in the area of medical image denoising due to its sparsity and multiresolution properties. The Discrete Wavelet Transform (DWT), which is based on sub-band coding is found to yield a fast computation of Wavelet Transform.

Keywords-Discrete wavelet transform, Gaussian noise, Image denoising, Salt and Pepper noise, Wavelet transform.

1. Introduction
Image denoising in digital image processing focuses on the removal of noise, which may disturb an image during its acquisition or transmission. MRI is most common tool for diagnosis in Medical field [2]. The quality of these images is degraded by most common Gaussian noise and Salt and pepper noise. Salt and pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level [3]. The presence of noise in the image has two disadvantages, the first being the degradation of the image quality and the second, more important, obscures important information required for accurate diagnosis [4]. In particular, edges are important features for MRI images. The great challenge of image denoising is how to preserve the edges and all fine details of an image when reducing the noise. Thus Denoising is often a necessary and the first step to be taken before the images data is analyzed. In this paper section 2 represents Wavelet Transform. Section 3 shows the Methodology, section 4 represents Thresholding. Section 5 shows the Advantages and disadvantages of DWT.

2. Wavelet Transform
Wavelets have been employed for denoising of images more than a decade. Wavelet transformation is a multiresolution representation of signal and image in two dependant domains, which decompose the signal and image into multiscale resolution. The localization of the wavelet basis functions in both time and frequency domain leads to multiresolution analysis and effective filter designs for specific applications. Wavelet decomposition preserved and depicted the sharp transition in images, which results in very accurate edge detection in images. These properties of the wavelet transform make it very effective for denoising. Wavelet gaining popularity in the area of biomedical image denoising due to its sparsity and multiresolution properties. In recent years, the multiresolution wavelet denoising techniques have employed in biomedical image. Several wavelets such as haar, daubechies, symlet, discrete meyer coiflets and biorthogonal have been implemented for denoising. Wavelet families are mainly distinguished into two categories: Orthogonal and Biorthogonal. Orthogonal wavelet families are, Daubechies, Coiflet and Symlet [5].

2.1 Discrete Wavelet Transform
The transform of a signal is just another form of representing the signal. It does not change the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal. It was developed to overcome the short coming of the Short Time Fourier Transform (STFT), which can also be used to analyze non-stationary signals. While STFT gives a constant resolution at all frequencies, the Wavelet Transform uses multi-resolution technique by which different frequencies are analyzed with different resolutions.

Wavelets are mathematical functions that analyze data according to scale or resolution [6]. They aid in studying a signal in different windows or at different resolutions. For instance, if the signal is viewed in a large window, gross features can be noticed, but if viewed in a small window, only small features can be noticed. Wavelets provide some advantages over Fourier transforms. For example, they do a good job in approximating signals with sharp spikes or signals having discontinuities. Wavelets can also model speech, music, video and non-stationary stochastic signals. Wavelets can be used in applications such as image compression, turbulence, human vision, radar, earthquake prediction, etc. [6]. The term "wavelets" is used to refer to a set of orthonormal basis functions generated by dilation and translation of scaling function φ and a mother wavelet ψ[7]. The finite scale multiresolution representation of a discrete function can be called as a discrete wavelet transform [7]. DWT is a fast linear operation on a data vector, whose length is an integer power of 2. This transform is invertible and orthogonal, where the inverse transform expressed as a matrix is the transpose of the transform matrix. The wavelet basis or function, unlike sines and cosines as in Fourier transform, is quite localized in space. But similar to sines and cosines, individual wavelet functions are localized in frequency.

The orthonormal basis or wavelet basis is defined as [8]

$\psi_{(j,k)}(x)=2^{j/2}\psi(2^j x-k)$ ………………..1)

The scaling function is given as [8]

$\phi_{(j,k)}(x)=2^{j/2}\phi(2^j x-k)$, ………………..2)

where ψ is called the wavelet function and *j* and *k* are integers that scale and dilate the wavelet function. The factor '*j*' in Equations (1) and (2) is known as the scale index, which indicates the wavelet's width. The location index *k* provides the position. The wavelet function is dilated by powers of two and is translated by the integer *k*. In terms of the wavelet coefficients, the wavelet equation [8] is

$\psi(x)=\sum_k^{N-1} gk\sqrt{2\phi(2x-k)}$, …………….3)

where *g0*, *g1*, *g2*,…. are high pass wavelet coefficients. Writing the scaling equation [14] in terms of the scaling coefficients as given below, we get

$\phi(x) = \sum_k^{N-1} hk\sqrt{2\phi(2x-k)}$. …………….4)

The function φ*(x)* is the scaling function and the coefficients *h0*, *h1*, *h2*,… are low pass scaling coefficients. The wavelet and scaling coefficients are related by the quadrature mirror relationship, which is

$gn = (-1)^n$ h1- n + N

The term *N* is the number of vanishing moments [8]. A graphical representation of DWT is shown in Figure2.1. Note that, *Y0* is the initial signal.

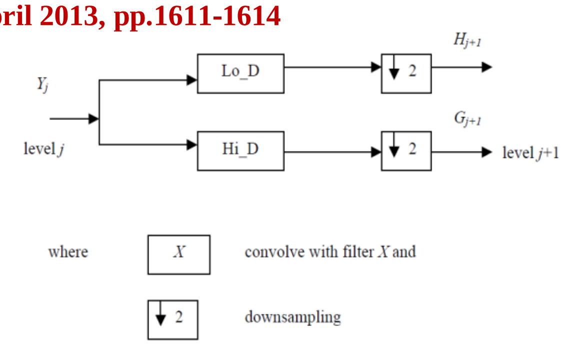

Fig 2.1: A 1-Dimensional DWT - Decomposition step

As mentioned earlier, the wavelet equation produces different wavelet families like Daubechies, Haar, coiflets, etc. [9]. Wavelets are classified into a family by the number of vanishing moments *N*. Within each family of wavelets there are wavelet subclasses distinguished by the number of coefficients and by the level of iterations. The filter lengths and the number of vanishing moments for four different wavelet families are tabulated in Table 2.1.

Table2.1:Wavelet families and their properties [10]

Wavelet Family	Filters length	Number of vanishing moments, *N*
Haar	2	1
Daubechies *M*	2*M*	*M*
Coiflets *M*	6*M*	2*M*-1
Symlets	2*M*	*M*

2.2 Characteristics of DWT

1) The wavelet transform decomposes the image into three spatial directions, i.e. horizontal, vertical and diagonal. Hence wavelets reflect the anisotropic properties of HVS more precisely [11].
2) Wavelet Transform is computationally efficient and can be implemented by using simple filter convolution.
3) Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, HL) [12].
4) The larger the magnitude of the wavelet coefficient the more significant it is.
5) Watermark detection at lower resolutions is computationally effective because at every successive resolution level there are few frequency bands involved.
6) High resolution subbands helps to easily locate edge in an image.

3. Methodology

The steps of the algorithm are as following:

- Take a medical image.
- Decompose the image using discrete wavelet transform.
- Estimation of a threshold.

- Choice of shrinkage rule and application of the threshold to the detail coefficients. This can be accomplished by hard or soft thresholding.
- Inverse of the wavelet transform (wavelet reconstruction) using modified (threshold) coefficients.

4. Thresholding

Thresholding approach is sensitive to noise components. The shrinkage rule defines how we apply the threshold[13]. Two main approaches of thresholding are:

i) Hard thresholding : In hard thresholding all coefficients whose magnitude is greater than the selected threshold value λ remains same and the others whose magnitude is smaller than λ are set to zero. It creates a region around zero where the coefficients are considered negligible.

ii) Soft thresholding: In soft thresholding, the coefficients whose magnitude is greater than the selected threshold value are shrunk towards zero by an amount of threshold λ and others set to zero.

The choice of a threshold plays an important role in the removal of noise in images because denoising most frequently produces smoothed images, reducing the sharpness of the image. Care should be taken so as to preserve the edges of the denoised image.

5. Advantages and Disadvantages of DWT

Advantages

1) Wavelet transform understands the HVS more closely.

2) Wavelet coded image is a multi-resolution description of image. Hence an image can be shown at different levels of resolution and can be sequentially processed from low resolution to high resolution.

3) Visual artifacts introduced by wavelet coded images are less evident because wavelet transform doesn't decompose the image into blocks for processing. At high compression ratios blocking artifacts are noticeable in wavelet coded images it is much clearer.

4) DWT has spatial frequency locality,which means if signal is embedded it will affect the image locally [14]. Hence a wavelet transform provides both frequency and spatial description for an image.

Disadvantages

Discrete Wavelet Transform also suffers from following problems:

1) Lack of shift invariance - when the input signal is shifted slightly, the amplitude of the wavelet coefficients varies so much.

2) Lack of directional selectivity - as the DWT filters are real and separable the DWT cannot distinguish between the opposing diagonal directions.

These problems delay the progress of using the wavelets. [15]

6. Conclusion

From their properties and behavior, wavelets play a major role in image compression and image denoising. DWT provides substantial improvement in picture quality at low bit rates because of overlapping basis functions and better energy compaction property of wavelet transforms. It is easy to implement and reduces the computation time and resources required. Though DWT has some disadvanteges but these can be overcome by using Dual Tree Discrete Wavelet Tranform and Stationary Wavelet Transform.

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