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An Approach to Reduce Speckle Noise in Ultrasound Images

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Declaration of Authorship

It is to certify that the following work was presented as a thesis from the result of analysis and investigation carried out by Mohammad Amranul Islam, Azwad Arman and Md. Soumik Farhan under the supervision of Md. Taslim Reza in the Department of Electrical and Electronic Engineering (EEE), IUT, Gazipur, Bangladesh and Co Supervision of Prof. Dr. Sheikh Kaiser Alam, Visiting Professor, Rutgers University, New Jersey, USA. It is declared that neither of the thesis nor any part of this thesis has been submitted anywhere else for any degree or Diploma. Information acknowledged in text and list of reference.

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ISLAMIC UNIVERSITY OF TECHNOLOGY

Abstract

Electrical and Electronic Engineering

B.Sc in Electrical and Electronic Engineering

An Approach to Reduce Speckle Noise in Ultrasound Images

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Medical Image processing is one of the most fundamental tool since the inception of medical science. For detecting and curing any disease, image processing in medical played a very vital role. Ultrasound imaging brought about a huge stepping stone for medical testing and in many other field.
But image disturbance has been the most backtracking effect in this case. Speckle Noising is one of the key disturbances and many have dedicated their efforts for denoising this defect
Our main area of concern is to reduce this noise up to a requisite amount so that the image can be used without any problem. In our approach we targeted the properties of Speckle Noise and tried different approaches to reduce overall noises.
We used Empirical Mode Decomposition(EMD) algorithm to our data (US Image) and observed the effect of EMD on such Data. In our work we used .rf DATA. We used the combination of SRAD, Wavelet Transformation (Double Density Discrete WT) and EMD. Then with the resultant data, we compared the image with different comparative parameters like MSE, PSNR and also observed their effect on lesion segmentation. For segmentation purpose we used watershed and seed growing method and obtained the result.

Keywords: Empirical Mode Decomposition (EMD), Speckle Reducing Anisotropic Diffusion (SRAD), Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Wavelet Transformation (Double Density Discrete WT), Ultrasound, Lesion segmentation.

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Chapter 1

Introduction

1.1 Introduction

Cancer is a group of diseases that cause cells in the body to change and grow out of control. Most types of cancer cells eventually form a lump or mass called a tumor, and are named after the part of the body where the tumor originates.

Breast cancer begins in the breast tissue that is made up of glands for milk production, called lobules, and the ducts that connect the lobules to the nipple. The remainder of the breast is made up of fatty, connective, and lymphatic tissues. Breast cancer typically produces no symptoms when the tumor is small and most easily cured. Therefore, it is very important for women to follow recommended screening guidelines for detecting breast cancer at an early stage. When breast cancer has grown to a size that can be felt, the most common physical sign is a painless lump. Sometimes breast cancer can spread to underarm lymph nodes and cause a lump or swelling, even before the original breast tumor is large enough to be felt.

1.2 Present Scenario

One in eight deaths worldwide is due to cancer[1]. Cancer is the second leading cause of death in developed countries and the third leading cause of death in developing countries. In 2009, about 562,340 Americans died of cancer, more than 1,500 people a day. Approximately 1,479,350 new cancer cases were diagnosed in 2009. In the United Sates, cancer is the second most common cause of death, and accounts for nearly 1 of every 4 deaths[2]. Breast cancer is the most common, life-threatening cancer among American women[3]. The chance of developing invasive breast cancer at some time in a woman's life is about 1 in 8 (12 %)[4,5]. Breast cancer continues to be a significant public health problem in the world. Approximately 182,000 new cases of breast cancer are diagnosed and 46,000 women die of breast cancer each year in the United States[6]. In 2009, 192,370 new cases of invasive breast cancer were diagnosed among women in the United States[3]. Thus, the incidence and mortality of breast cancer are very high, so much so that breast cancer is the second leading cause of cancer death in women. The chance that breast cancer will be responsible for a woman's death is about 1 in 35 (about 3%)[4].In 2009, about 40,610 women died from breast cancer in the United States[7]. Although breast cancer has very high incidence and death rate, the cause of breast cancer is still unknown[4]. No effective way to prevent the occurrence of breast cancer exists. Therefore, early detection is the first crucial step towards treating breast cancer. It plays a key role in breast cancer diagnosis and treatment. The technological boom in every aspect has made researchers to ponder over a screening tool that can be used to detect tumor in its developing stage, which can be used by the surgeons for further diagnosis.

FIGURE 1.1: Average Number of New Cases per Year and Age-Specific Incidence Rates per 100,000 Population, Females, UK 2011 (Cancer Research UK)

According to the IOM (U.S. Institute of Medicine) report, an ideal breast screening tool[8]

- Has minimal health risk;
- Sensitive to tumors;
- Early cancer detection capability;
- Non-invasive and easy to perform;
- Cost effective, easy to understand & consistent;
- Provides minimum discomfort to patients

For detection of small tumor(s), a consistent contrast between tumor and normal breast tissues is required. Medical imaging methods have been applied to breast cancer detection with various degrees of success[8]. Early detection of cancers can reduce unnecessary biopsies in a drastic manner which will result in less hazards for the patients under diagnosis.

1.3 Screening Techniques and Ultrasound Imaging

Breast cancer screening is vital to detecting breast cancer. The most common screening methods are mammography and sonography. Ultrasound imaging has proved to be a valuable addition to mammography in the detection and classification of breast lesions[9]. Due to low specificity Mammography can detect false positives resulting in unnecessary biopsy operations. Also Mammography is ineffective in detecting breast cancer in adolescent women because of ongoing breast tissue formation in that age period.

Ultrasound (US) imaging technique is far superior to the other imaging modalities in many aspects. Firstly, Ultrasound is a non-invasive method for imaging causing almost no hazard for the patients undergoing the diagnosis; secondly, it is a very suitable for people of all classes, especially the developing countries as it is a very low cost diagnosis technique. Also another vital point that makes it superior to other techniques is that it does not expose the patients to any radiation so US imaging is very safe for the patients. Magnetic Resonance Imaging (MRI) is very widely used but still this test cannot be performed during pregnancy or to a patient having heart problems due to application of a huge magnetic field. Ultrasound image can classify benign and malignant type of tumors which is another feature that puts US imaging above other imaging modalities. The dissemination of breast cancer disease is reported to increase rapidly due to the shortcomings in the currently used screening methods, where X-ray mammography is the widely used screening technique amongst MRI to detect breast tumors however it has been reported to have estimated false results for around 30% of women who have had a screening[10-11]. The considerable amount of false results obtained is noticeably the limitation of the present screening methods in analyzing dense breast tissue and the area where the tumor might be located close to the chest or under the arm and mainly the estimation of early stage tumors[12]. Keeping these issues in mind US imaging is capable of detecting less false detection which makes it efficient in detecting tumor lesions. Comparing with the other Computer Aided Diagnosis available currently US imaging is more reliable and at the same time cost-effective. Ensuring maximum safety to the patients US imaging can be very helpful in classifying benign and malignant type of cancers. Developing countries and also countries possessing fewer resources will be able to facilitate the cancer detection using US imaging within their restraints.

1.4 Thesis Objective

The thesis mainly focuses on devising an automatic computer-aided system which will be capable of processing input ultrasound image. The main objectives of the thesis can be summarized as follows:

- To observe the segmented lesion part of US image by applying EMD, Wavelet.

- How effectively it detects lesion part by applying these algorithm is our main concern.

1.5 Thesis Organization

The thesis has been arranged in the following way-

•**In Chapter 2**, the basic theory behind Ultrasound Imaging and brief Idea Regarding Ultrasound process using ultrasound machines and several inherent feature of BUS image.

•**In Chapter 3**, Speckle Noise and some of its property with discussion regarding its nature.

•**In Chapter 4**, one of the diffusion used for filtering the required Image, SRAD is discussed along with its algorithm and properties.

•**In Chapter 5**, Wavelet and Wavelet Transformation is discussed in brief.

•**In Chapter 6**, the main basic process used for the whole work of our thesis is discussed i.e. Empirical Mode Decomposition.

•**In Chapter 7**, Qualitative Evaluation of Segmentation Result is given with required discussion.

Chapter 2

Ultrasound

2.1 What is Ultrasound?

Simply stated, ultrasound is sound whose frequency is above the range of human hearing. Diagnostic ultrasound is used to evaluate a patient's internal organs. Sound waves are transmitted into the body; then, because the various internal structures reflect and scatter sound differently, returning echoes can be collected and used to form an image of a structure.
Sound waves consist of mechanical variations containing condensations or compressions (zones of high pressure) and rarefactions (zones of low pressure) that are transmitted through a medium.
Unlike X-Rays, sound is not electromagnetic. Matter must be present for sound to travel, which explains why sound cannot propagate through a vacuum. Propagation of sound is the transfer of energy from one place to another within a medium, some energy is also imparted to the medium.
Sound is categorized according to its frequency (number of mechanical variations occurring per unit time)[13]:

Human Audible range	20 to 20000Hz
Diagnostic Ultrasound	1 to 20MHz
.	(3-12MHz being the most common range)

2.2 The generation of ultrasound

The ultrasonic transducer is the one responsible for generating ultrasound and recording the echoes generated by the medium. Since the transducer should make mechanical vibrations in the megahertz range, a material that can vibrate that fast is needed. Piezoelectric materials are ideal for this.

The typical transducer consist of a disk-shaped piezoelectric element that is made vibrating by applying an electrical impulse via an electrode on each side of the disc. Likewise, the echo returning to the disk makes it vibrate, creating a small electrical potential across the same two electrodes that can be amplified and recorded[13]. In modern clinical scanners, the transducer consists of hundreds of small piezoelectric elements arranged as a 1D array packed into a small enclosure. The shape of this line can be either linear or convex. The use of arrays with hundreds of elements, makes it possible to electronically focus and steer the beam.

2.3 Piezoelectricity

The acoustic field is generated by using the piezo electric effect present in certain ceramic materials. Electrodes (e.g. thin layers of silver) are placed on both sides of a disk of such a material. One side of the disk is fixed to a damping so-called backing material, the other side can move freely. If a voltage is applied to the two electrodes, the result will be a physical deformation of the crystal surface, which will make the surroundings in front of the crystal vibrate and thus generate a sound field. If the material is compressed or expanded, as will be the case when an acoustic wave impinges on the surface, the displacement of charge inside the material will cause a voltage change on the electrodes. This is used for emission and reception of acoustic energy, respectively.

2.3.1 Ultrasound's interaction with the medium

The interaction between the medium and the ultrasound emitted into the medium can be described by the following phenomena:
The echoes that travel back to the transducer and thus give information about the medium is due to two phenomena: reflection and scattering. Reflection can be thought of as when a billiard ball bounces off the barrier of the table, where the angle of reflection is identical to the angle of incidence. Scattering (Danish: spredning)[14] can be thought of, when one shines strong light on the tip of a needle: light is scattered in all directions. In acoustics, reflection and scattering is taking place when the emitted pulse is travelling through the interface between two media of different acoustic properties, as when hitting the interface of an object with different acoustic properties.

FIGURE 2.1: Ultrasound beams are coming out sequentially from the Ultrasound transducer[Reference: Internet[28]]

Specifically, reflection is taking place when the interface is large relative to the wavelength (e.g. between blood and intima in a large vessel). Scattering is taking place when the interface is small relative to the wavelength (e.g. red blood cell).

The abstraction of a billiard ball is not complete, however: In medical ultrasound, when reflection is taking place, typically only a (small) part of the wave is reflected. The remaining part is transmitted through the interface. This transmitted wave will nearly always be refracted, thus typically propagating in another direction. The only exception is when the wave impinges perpendicular on a large planar interface: The reflected part of the wave is reflected back in exactly the same direction as it came from (like with a billiard ball) and the refracted wave propagates in the same way as the incident wave.

Reflection and scattering can happen at the same time, for instance, if the larger planar interface is rough. The smoother, the more it resembles pure reflection (if it is completely smooth, specular reflection takes place). The rougher, the more it resembles scattering.

When the emitted pulse travels through the medium, some of the acoustic (mechanical) energy is converted to heat by a process called Absorption. Of course, also the echoes undergo absorption.
Finally, the loss in intensity of the forward propagating acoustic pulse due to reflection, refraction, scattering and absorption is under one named attenuation.

2.4 Imaging

Imaging is based on the pulse-echo principle[14]: A short ultrasound pulse is emitted from the transducer. The pulse travels along a beam pointing in a given direction. The echoes generated by the pulse are recorded by the transducer. This electrical signal is always referred to as the received signal. The later an echo is received, the deeper is the location of the structure giving rise to the echo. The larger the amplitude of the echo received, the larger is the average specific acoustic impedance difference between the structure and the tissue just above. An image is then created by repeating this process with the beam scanning the tissue.
All this will now be considered in more detail by considering how Amplitude mode, Motion mode and Brightness mode work.

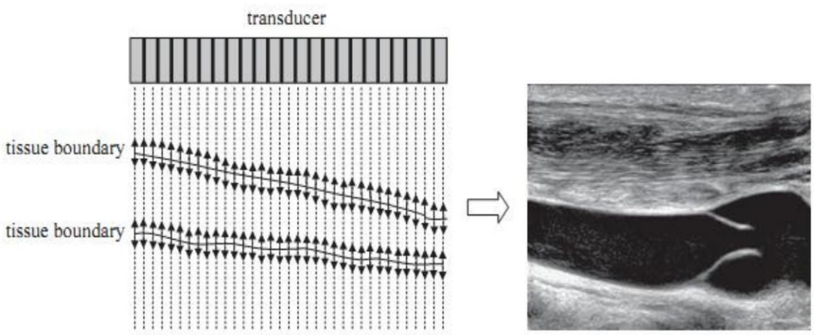

FIGURE 2.2: Image reproduction from the Ultrasound beam[14]

2.4.1 A-mode:

The basic concept behind medical diagnostic ultrasound , which also shows the simplest mode of operation, A-mode. In the situation a single point scatter is located in front of the transducer at depth d. A short pulse is emitted from the transducer, and at time 2d/c, the echo from the point target is received by the

same transducer. Thus, the deeper the point scatter is positioned, the later the echo from this point scatter arrives. If many point scatter (and reflectors) are located in front of the transducer, the total echo can be found by simple superposition of each individual echo, as this is a linear system, when the pressure amplitude is sufficiently low.
The scan line is created by calculating the envelope (Danish: indhyllingskurve)[14] of the received signal followed by calculation of the logarithm, in order to compress the range of image values for a better adoption to the human eye. So, the scan line can be called a gray scale line. The M-mode and B-mode images are made from scan lines.

2.4.2 M-mode:

If the sequence of pulse emission and reception is repeated infinitely, and the scan lines are placed next to each other (with new ones to the right), motion mode, or M-mode, is obtained. The vertical axis will be depth in meters downwards, while the horizontal axis will be time in seconds pointing to the right. This mode can be useful when imaging heart valves, because the movement of the valves will make distinct patterns in the "image".

2.4.3 B-mode:

Brightness or B-mode is obtained by physically moving the scan line to a number of adjacent locations. The principle is shown in Figure 10. In this figure, the transducer is moved in steps mechanically across the medium to be imaged. Typically 100 to 300 steps are used, with a spacing between 0.25 lambda and 5 lambda. At each step, a short pulse is emitted followed by a period of passive registration of the echo. In order to prevent mixing the echoes from different scan lines, the registration period has to be long enough to allow all echoes from a given emitted pulse to be received. This will now be considered in detail.

2.5 Challenges in Ultrasound:

Ultrasound imaging has been the ultimate method of gaining exquisite result in the field of medical imaging. But some inherent noise comes in package with the images formed from the subject. These are, in fact, our cause to be alert and form this pattern to remove (mainly reduce) this noises in ultrasound images:

- Speckle Noise
- Low Contrast
- Low signal/noise ratio
- Indecisive boundary walls between subject

Chapter 3

Speckle Noise:

3.1 Introduction

Medical images are usually corrupted by noise in its acquisition and Transmission. The main objective of Image de noising techniques is necessary to remove such noises while retaining as much as possible the important signal features. Introductory section offer brief idea about different available de noising schemes. Ultrasonic imaging is a widely used medical imaging procedure because it is economical, comparatively safe, transferable, and adaptable. Though, one of its main shortcomings is the poor quality of images, which are affected by speckle noise. The existence of speckle is unattractive since it disgrace image quality and it affects the tasks of individual interpretation and diagnosis. Accordingly, speckle filtering is a central pre-processing step for feature extraction, analysis, and recognition from medical imagery measurements. Previously a number of schemes have been proposed for speckle mitigation.

An appropriate method for speckle reduction is one which enhances the signal to noise ratio while conserving the edges and lines in the image. Filtering techniques are used as preface action before segmentation and classification. On the whole speckle reduction can be divided roughly into two categories. The first one recovers the image by summing more than a few observations of the same object which suppose that no change or motion of the object happened during the reception of observations. Statistical filter like Weiner filter adopted filtering in the spectral domain, but the classical Wiener filter is not adequate while it is designed primarily for additive noise suppression. To address the multiplicative nature of speckle noise, Jain developed a homomorphic approach, which by obtaining the logarithm of the image, translates the multiplicative noise into additive noise, and consequently applies the Wiener. Adaptive filter takes a moving filter window and estimates the statistical information of all pixels' grey value[14], such as the local mean and the local variance. The central pixel's output value is dependent on the statistical information.

Adaptive filters adapt themselves to the local texture information surrounding a central pixel in order to calculate a new pixel value. Adaptive filters generally incorporate the Kuan filter, Lee filter, Frost filter, Gamma MAP filters. These filters made obvious their superiority measured up to low pass filters, since they have taken into account the local statistical properties of the image. Adaptive filters present much better than low-pass smoothing filters, in preservation of the image sharpness and details while suppressing the speckle noise. In most natural images counting medical images, there in general exists a context models like Markov random fields, for example, wavelet-based de noising using Hidden Markov Tree has been quite successful, and it gave rise to a number of other HMT-based schemes. They tried to model the dependencies among adjacent wavelet coefficients using the HMT and used the Minimum Mean-Squared Error like estimators for suppressing the noise.

3.2 Speckle Noise in Ultrasound Image

It is an ultrasound-based diagnostic medical imaging technique used to visualize muscles and many internal organs, their size, structure and any pathological injuries with real time tomographic images. It is also used to visualize a fetus during routine and emergency prenatal care. Obstetric sonography is commonly used during pregnancy. It is one of the most widely used diagnostic tools in modern medicine. The technology is relatively inexpensive and portable, especially when compared with other imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT). It has no known long-term side effects and rarely causes any discomfort to the patient. Small, easily carried scanners are available; examinations can be performed at the bedside. Since it does not use ionizing radiation, ultrasound yields no risks to the patient. It provides live images, where the operator can select the most useful section for diagnosing thus facilitating quick diagnoses. This work aims to suppress speckle in Ultrasound images.

Speckle noise affects all coherent imaging systems including medical ultrasound. Within each resolution cell a number of elementary scatters reflect the incident wave towards the sensor. The backscattered coherent waves with different phases undergo a constructive or a destructive interference in a random manner.[16] The acquired image is thus corrupted by a random granular pattern, called speckle that delays the interpretation of the image content.

In the medical literature, speckle noise is referred as “texture”, and may possibly contain useful diagnostic information. The desired grade of speckle smoothing preferably depends on the specialist’s knowledge and on the application. For automatic segmentation, sustaining the sharpness of the boundaries between different image regions is usually preferred while smooth out the speckled texture. For visual interpretation, smoothing the texture may be less desirable.

Physicians generally have a preference of the original noisy images more willingly than the smoothed versions because the filters even if they are more sophisticated can destroy some relevant image details. Thus it is essential to develop noise filters which can secure the conservation of those features that are of interest to the physician. The wavelet transform has recently entered the field of image de noising and it has firmly recognized its stand as a dominant de noising tool.

FIGURE 3.1: Image Without Noise[16]

FIGURE 3.2: Image With Noise[16]

3.2.1 Reason of Occurrence

Nature of Speckle pattern depends on the number of scatters per resolution cell or scatter number density. Spatial distribution and the characteristics of the imaging system can be divided into three classes[15]:

•The fully formed speckle pattern occurs when many random distributed scattering exists within the resolution cell of the imaging system. Blood cells are the example of this class.

•The second class of tissue scatters is no randomly distributed with long-range order. Example of this type is lobules in liver parenchyma.

•The third class occurs when a spatially invariant coherent structure is present within the random scatter region like organ surfaces and blood vessels.

3.2.2 Properties of Speckle Noise

• Speckle noise is multiplicative, signal dependent noise and for this reason the signal-to-noise ratio in the image is equal to unity.

• If we consider Probability Distribution of Image, the statistics of the speckle noise are therefore additive and signal independent.

• Film granularity increases with density, whereas speckle granularity is constant.

• Let us assume that the image consists of a Cartesian array of cells. This array form into grey levels. These grey levels are filled with noise. Now grey level retrieval can be accomplished only by sacrificing image resolution.

• A time exposure in the image plane then results in the addition, on an intensity basis, of a number of uncorrelated speckle patterns, thus suppressing the contrast of the detected speckle pattern.

• Speckle pattern which greatly influences its effects on optical system performance is the coarseness of the granularity in the pattern.

• A speckle pattern consists of peaks and nulls of many different scale sizes, so many measure coarseness indicate an average distribution of speckle.

Speckle patterns is generated in relatively smooth surfaces[16].

Chapter 4

Speckle Reducing Anisotropic Diffusion

4.1 Iintroduction

The fundamental and statistical properties of speckle noise have been described in many studies. Most frequently, Rayleigh and Rician models are used to study speckle noise. Many papers have shown that, in the case of many fine randomly distributed scatters per resolution cell the speckle can be modeled by a Rayleigh distribution Some less widely used models are also found in the literature, including the Rician inverse Gaussian , the Nakagami inverse Gaussian and the generalized Nakagami distribution.

Speckle reduction methods have been discussed in many reports. Popular methods include the Lee method, the Kuan method, the PM equation, speckle-reducing anisotropic diffusion (SRAD), detail-preserving anisotropic diffusion (DPAD) oriented speckle-reducing anisotropic diffusion (OSRAD), the Rayleigh maximum likelihood (R-ML) method and the use of anisotropic Wiener filters[19].

4.2 Anisotropic Diffusion

Anisotropic Diffusion is a technique applied at reducing image noise without removing significant parts of the signal or image content.

4.3 Speckle Reducing Anisotropic Diffusion (SRAD)

SRAD is the edge-sensitive diffusion for speckled images, in the same way that conventional anisotropic diffusion is the edge-sensitive diffusion for images corrupted with additive noise. Speckle Reducing Anisotropic Diffusion (SRAD) is a partial differential equation (PDE) approach to remove speckle noise.

It is mainly filtering an image or signal by Mainly Lee, Kaun, Frost filters.

It is also called Perona and Malik approach[17].

There are two methods in proceeding towards proposed task i.e. Linear (Lee Filter) and Nonlinear (Kaun filter) method. Other filters are based on these two filters.

$$\partial I/\partial t = div[c(|\nabla I|).\ \nabla I] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$I(t=0) = Io \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Here $\bigtriangledown$ is gradient operator, div the divergence operator, c ($\bigtriangledown$ I) denotes the diffusion coefficient, Io, the initial image

4.3.1 Details of SRAD

The number of scatters per resolution cell is also called the scatter number density (SND), to their spatial distribution and to the characteristics of the imaging system.

• SRAD considers this SND and forms a region of interest in the image where it calculates the number of speckle noise.

• The filter proposed by Lee was derived from the simple filter proposed by Wallis where each pixel is required to have a “desirable” local mean and a “desirable local variance”.

• The difference between the Kaun and the Lee filter for multiplicative noise is that the Lee filter and Kaun Filter would use different constants for filtering[18].

4.3.2 Advantages of SRAD

Compared to Perona and Malik's anisotropic diffusion, the SRAD has the advantage of avoiding the threshold on the norm of the gradient needed for the diffusion function[17]. This threshold is replaced by an estimation of the standard deviation of the noise at each iteration which gives to SRAD the following advantages:

• One less independent parameter. It only considers information from image or signal. External parameters are not included in calculation.

• Less dependence on the norm of the gradient which can vary in the image.

• A natural decrease of the diffusion as the estimated as the standard deviation of the noise decreases: as σn $\rightarrow 0$; so computations converge without smoothing out interesting features of the image.

Chapter 5

Wavelet Transformation

5.1 Introduction:

The Discrete Wavelet Transform (DWT) of image signals produces a non-redundant image representation, which provides better spatial and spectral localization of image formation, compared with other multi scale representations such as Gaussian and Laplacian pyramid. Recently, Discrete Wavelet Transform has attracted more and more interest in image de-noising.

5.2 Wavelet:

Wavelets are functions that are concentrated in time as well as in frequency around certain points. A wavelet is a wave -like oscillation with an amplitude that begins at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor.

All wavelet transforms may be considered forms of time frequency representation for continuous time (analog) signals and so are related to harmonic analysis.

5.3 Introduction to wavelet families:

The Haar, Daubechies, Symlets, Mexican Hat and Coiflets are various types of wavelets[20]. Also using numerous mathematical model we can customize our own wavelet. These wavelets are competent of ideal reconstruction. We are using Haar and Daubechies wavelets in our algorithm.

5.3.1 Haar wavelet:

Haar wavelet is one of the oldest and simplest type of wavelet. The Haar Transform provides sample for all other wavelet transforms. Like other wavelet transforms, the Haar Transform decomposes the discrete signal into two subsignals of half of its length. One sub signal is a successively average or trend and other sub-signal is successively difference or fluctuation. The advantage of Haar wavelet is that it is rapid, memory competent and conceptually simple.

5.3.2 Daubechies Wavelet:

A family of wavelet transforms exposed by Ingrid Daubechies .The Concepts are very much similar to Haar but differs in how scaling functions and wavelets are defined. Daubechies wavelets are ready to lend a hand in compression and noise elimination of audio signal processing because of its property of overlapping windows and the high frequency coefficient spectrum that reflects all high frequency changes.

5.4 Similarity with the Fourier transform:

Fourier transform has the drawback of dealing with frequency components and wavelet transformation deals with both time and frequency component[22]. Wavelet transform decomposes a signal into a set of basic functions

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi(\frac{t-b}{a}) \quad \text{... ... ... (3)}$$

Wavelets are obtained from a single prototype wavelet y (t) called mother wavelet by dilations and shifting

$$W_f(a,b) = \int_{-\infty}^{\infty} x(t)\psi_{a,b}(t)dt \quad \text{... ... ... (4)}$$

Where a is the scaling parameter and b is the shifting parameter

5.5 Double-Density Discrete Wavelet Transform

Basic Double-Density Discrete Wavelet Transform goes as

•Wavelet can be used to divide information of an image into approximation and detail sub signal

•The approximation sub signal shows general trend of pixel values and three detail sub signals on the horizontal, vertical and diagonal details.

•If these are small, they can be set to zero without any significant changes in the image. Hence filtering and compression can be achieved.

By finding out the required detail of our image, we can remove one part of the result and trace it back to the original image which leaves the image with less amount of noise than the original one.

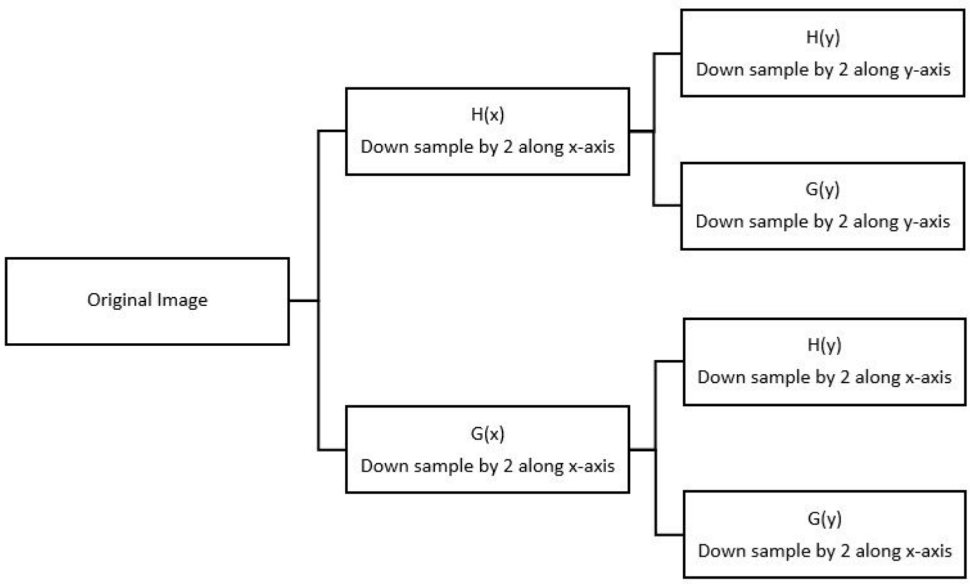

FIGURE 5.1: Algorithm for Double Density Discrete Wavelet Transform[22]

5.5.1 Discrete Wavelet Transform:

The DWT can be interpreted as signal decomposition[21] in a set of independent, spatially oriented frequency channels. The signal S is passed through two complementary filters and emerges as two signals, approximation and Details. This is called decomposition or analysis. The components can be assembled back into the original signal without loss of information. This process is called reconstruction or synthesis. The mathematical manipulation[23], which implies analysis and synthesis, is called discrete wavelet transform and inverse discrete wavelet transform. An image can be decomposed into a sequence of different spatial resolution images using DWT. In case of a 2D image, an N level decomposition can be performed resulting in 3N+1 different frequency bands namely, LL, LH, HL and HH as shown in figure 1. These are also known by other names, the sub-bands may be respectively called a1 or the first average image, h1 called horizontal fluctuation, v1 called vertical fluctuation and d1 called the first diagonal fluctuation. The sub-image a1 is formed by computing the trends along rows of the image followed by computing trends along its columns. In the same manner, fluctuations are also created by computing trends along rows followed by trends along columns. The next level of wavelet transform is applied to the low frequency sub band image LL only. The Gaussian noise will nearly be averaged out in low frequency wavelet coefficients. Therefore, only the wavelet coefficients in the high frequency levels need to be thresholded.

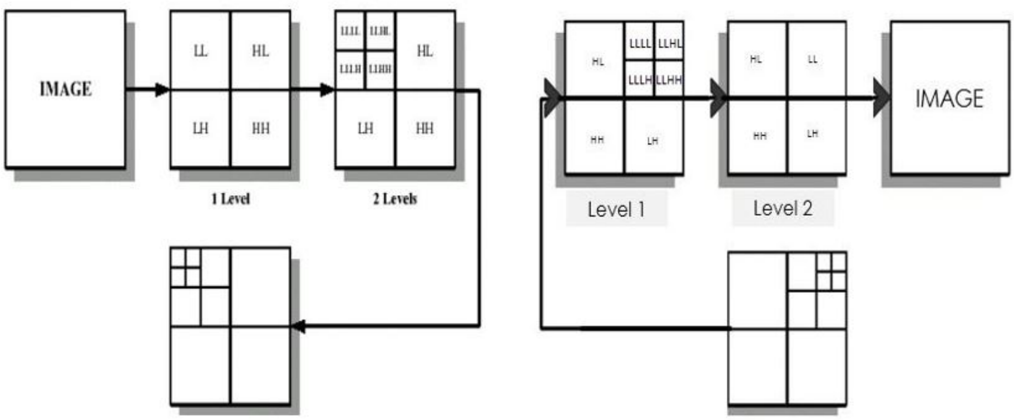

FIGURE 5.2: Basic Structure of Discrete Wavelet Transform

Steps that are implemented are:

• Wavelet can be used to divide information of an image into approximation and detail sub signal

• The approximation sub signal shows general trend of pixel values and three detail sub signals on the horizontal, vertical and diagonal details.

• If these are small, they can be set to zero without any significant changes in the image. Hence filtering and compression can be achieved.

By finding out the required detail of our image, we can remove one part of the result and trace it back to the original image which leaves the image with less amount of noise than the original one

Chapter 6

Empirical Mode Decomposition

6.1 Introduction:

Empirical Mode Decomposition (EMD) has been proposed recently (Huang, et al.1998, Huang et al. 1999) as an adaptive time-frequency data analysis method. It has proven to be quite versatile in a broad range of applications for extracting signals from data generated in noisy nonlinear and non-stationary processes (see, for example, Huang and Shen, 2005, Huang and Attoh-Okine, 2005)[24]. As useful as EMD proved to be, it till leaves some difficulties unresolved.

One of the major drawbacks of the original EMD is the frequent appearance of mode mixing, which is defined as a single Intrinsic Mode Function (IMF) either consisting of signals of widely disparate scales, or a signal of a similar scale residing in different IMF components. Mode mixing is a consequence of signal intermittency. As discussed by Huang et al. (1998 and 1999), the intermittence could not only cause serious aliasing in the time-frequency distribution, but also make the individual IMF devoid of physical meaning. To alleviate this from occurring Huang et al. (1999) proposed the intermittence test, which can indeed ameliorate some of the difficulties. However, the approach itself has its own problems: First, the intermittence test is based on a subjectively selected scale. With this subjective intervention, the EMD ceases to be totally adaptive. Secondly, the subjective selection of scales works if there are clearly separable and definable time scales in the data. In case the scales are not clearly separable but mixed over a range continuously, as in the majority of natural or man-made signals, the intermittence test algorithm with a subjectively defined time scales often does not work very well.

6.2 Empirical Mode Decomposition

The EMD is locally adaptive and suitable for analysis of nonlinear or non-stationary processes[24]. The starting point of EMD is to consider oscillatory signals at the level of their local oscillations and to formalize the idea that:

"Signal = fast oscillations sub imposed to slow oscillations"

And to iterate on the slow oscillation components considered as a new signal. This one-dimensional decomposition technique extracts a finite number of oscillatory components or "well-behaved" AM–FM functions, called intrinsic mode function (IMF), directly from the data.

The IMFs are obtained from the signal by means of an algorithm called the sifting process[28]. The sifting procedure is based on two constraints: each IMF has the same number of zero-crossings and extreme, and also has symmetric envelopes defined by the local maxima, and minima, respectively. Furthermore, it assumes that the signal has at least two extreme. So, for any one-dimensional discrete signal, I ori, EMD can finally be presented with the following representation:

$$I_{ori} = \sum_{j=0}^{J} I_{mode}(\mathrm{j}) + I_{res} \dots \dots \dots \dots \dots (5)$$

Where I mode (j) is the j- th mode (or IMF) of the signal, and Ires is the residual trend (A low-order polynomial component). The sifting procedure generates a finite (and limited)[25] number of IMFs that are nearly orthogonal to each other.

It is the EMD itself that is of interest from the compression perspective. It is a totally adaptive decomposition of the signal into its intrinsic modes, independent of any filters, cost functions or uncertainty principles. The IMF: s catches the signal components in a very compact way in well behaved signals leading to a clean representation by a few components.

6.3 Sifting process for IMF

A function is an IMF if it fulfills the following demands: It has the same number of zero crossings and extreme. Or the number of zero crossings and extreme differs only by one[26]. Further, the envelopes defined by the local maxima and minima respectively are symmetric.

The IMF is found by the sifting process:

1. Find all the local max points and all the local min points of the signal.

2. Create upper envelope by spline interpolation of the local maxima and the lover envelope by spline interpolation of the local minima of the input signal.

3. For each time, take the mean of the upper envelope and the lover envelope.

4. Subtract the mean signal from input signal.

5. Check if mean signal is close enough to zero. If not, repeat the process from 1. With the result signal from 4 as input signal. If it is the result is IMF, define the residue as result from IMF subtracted from input signal

6. Find next IMF by starting over from 1 with the residue as input signal

The basic Algorithm goes like this

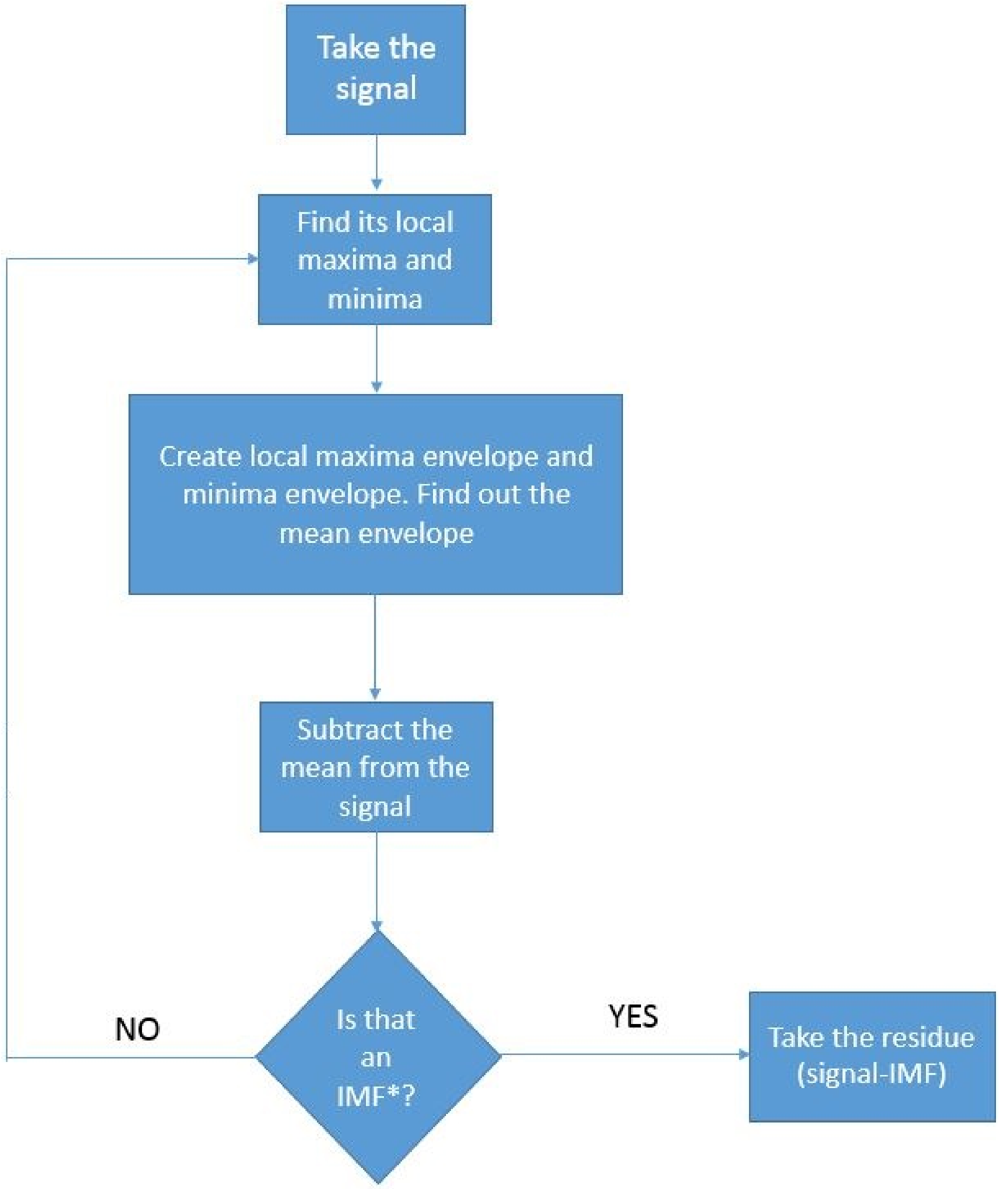

FIGURE 6.1: Algorithm for Empirical Mode Decomposition

*IMF criterion depends on standard deviation. In our approach we have taken standard deviation value: 0.3

6.3.1 Effect of EMD on a signal

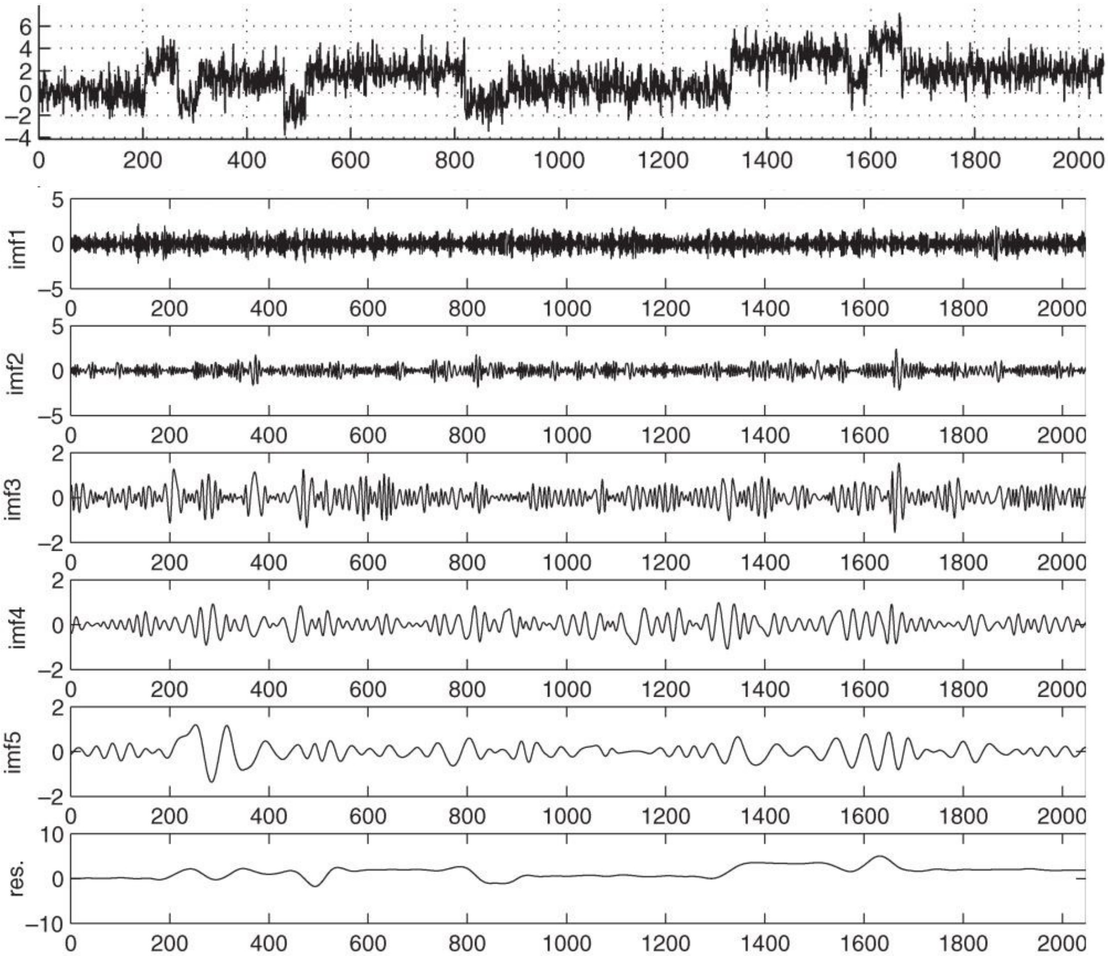

FIGURE 6.2: Basic Signal EMD implementation[27]

Chapter 7

Result and Demonstration

7.1 Summery of Contribution

In solving the problem at hand, we have applied the following steps regarding the denoise process.

• We want to denoise the ultrasound image by applying EMD and see how it works out on the US image also on a local image and then compare the results

• We have applied EMD on the US image in various ways (Row wise, Column wise, using the absolute Hilbert transform, not using the absolute Hilbert transform). Unfortunately the results aren't satisfactory.

• Although the standard image comparing parameters (MSE,SNR,PSNR) were satisfactory, but the images weren't visible properly

• SRAD and Wavelet Transformation have shown remarkable results in their respective fields.

• We combined this two methods in reducing the noises to give the requisite result.

• We have already applied EMD, wavelet and EMD wavelet together.

• We have applied segmentation to the result and observed their effect.

For better comparison we have provided the PSNR table to observe the effect of the algorithm

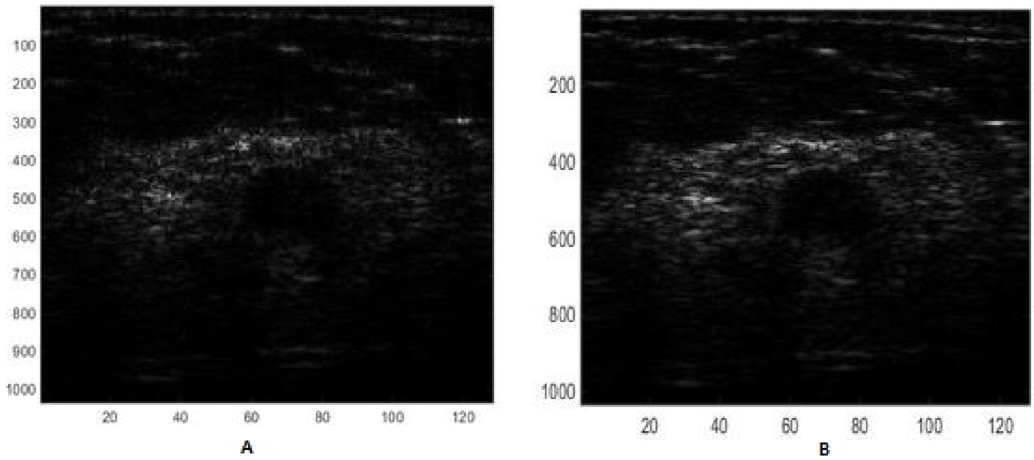

FIGURE 7.1: (A) Noisy Ultrasound image
(B) Noisy Ultrasound image

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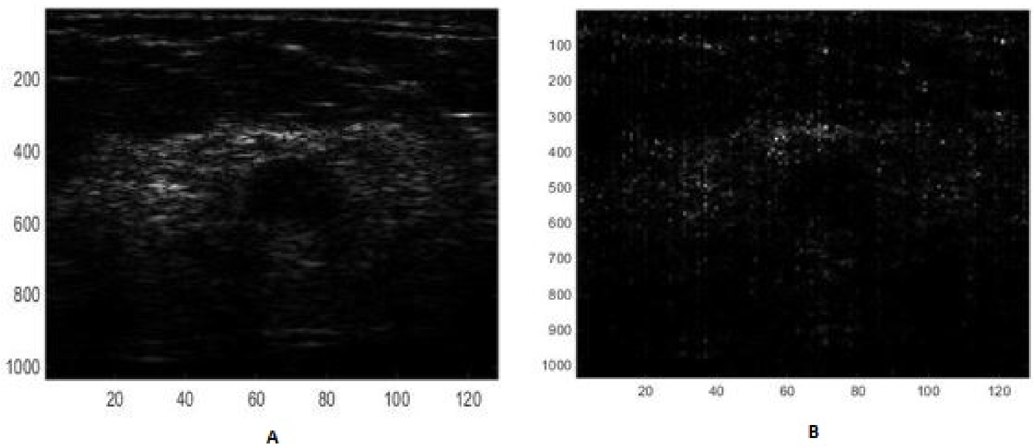

FIGURE 7.2: (A) 6th iteration (B) IMF1

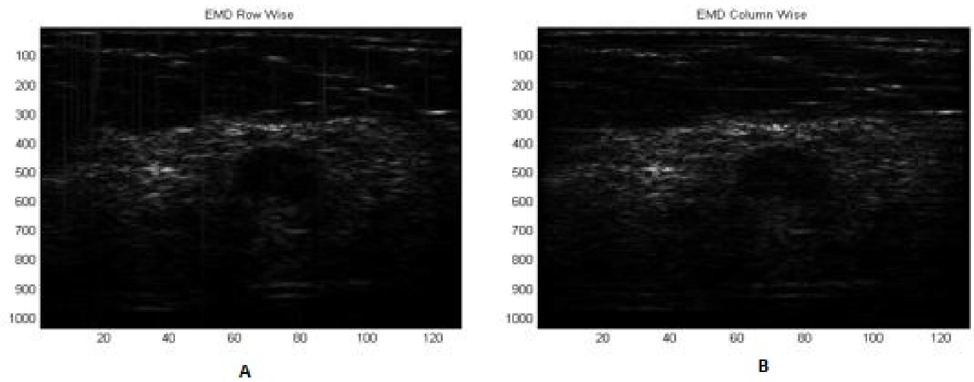

FIGURE 7.3: (A) EMD Row wise (B) EMD Column wise

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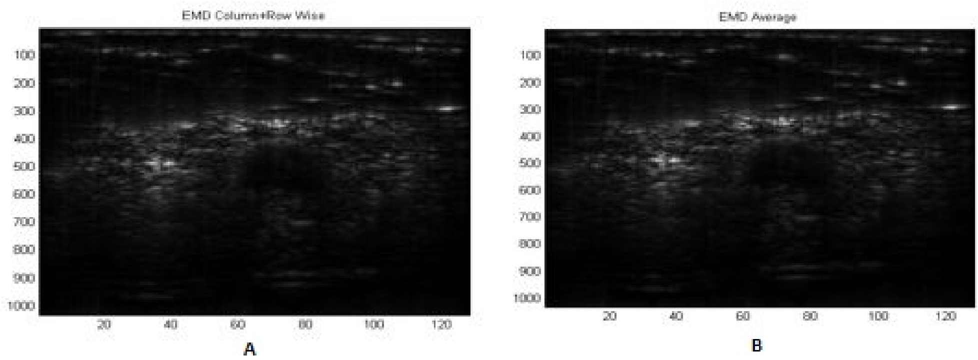

FIGURE 7.4: (A) EMD Column + Row wise (B) EMD Average

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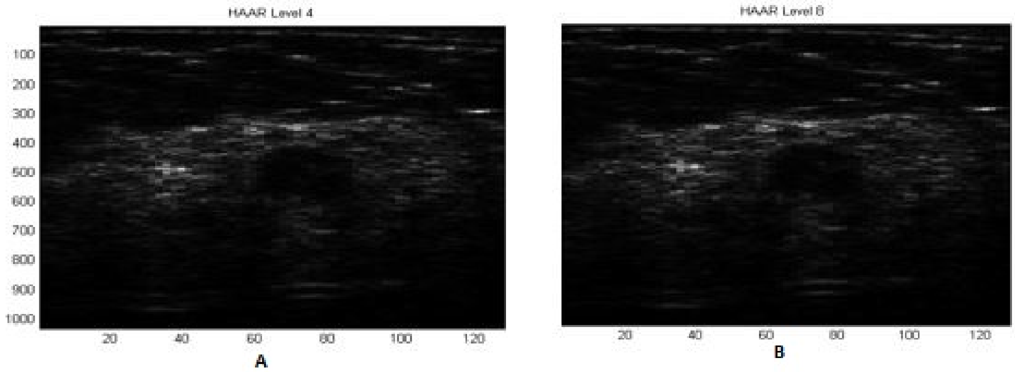

FIGURE 7.5: (A) HAAR Level 4 (B) HAAR Level 8

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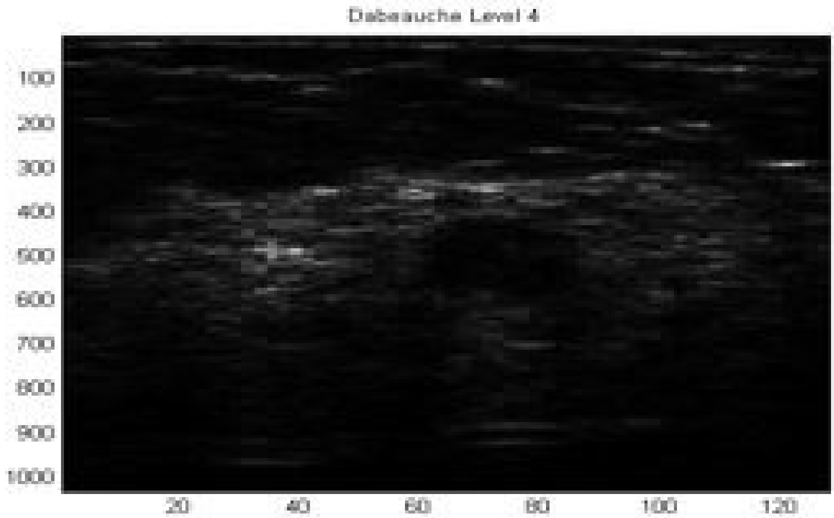


FIGURE 7.6: Dabeauche Level 4

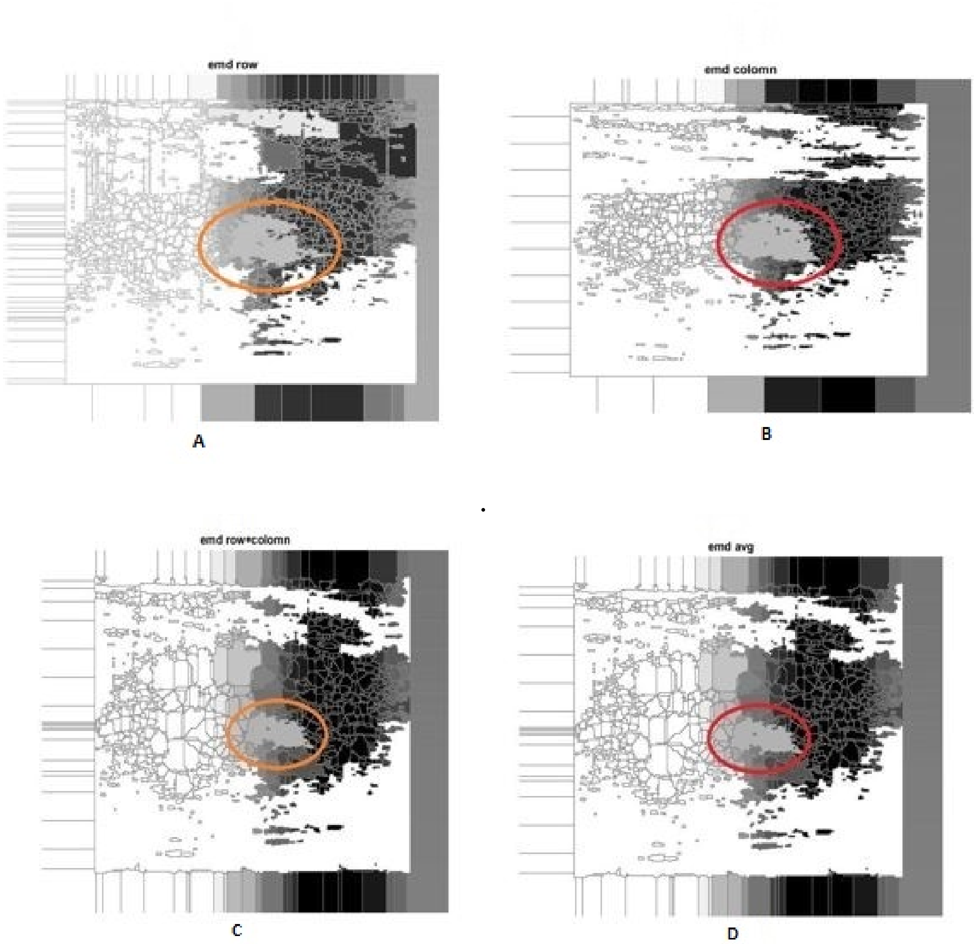
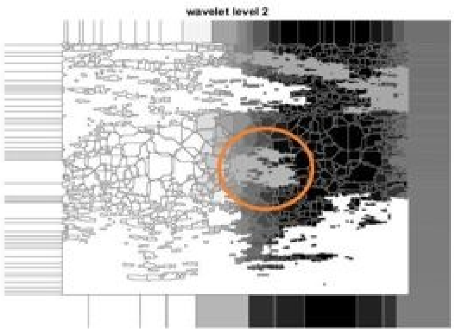
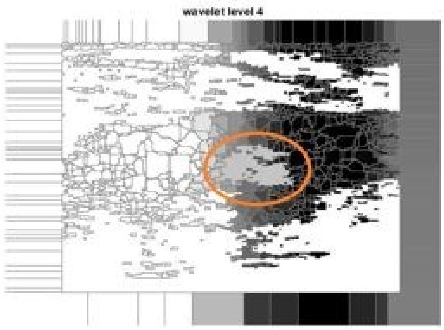


FIGURE 7.7: (A) EMD Row wise (B) EMD Column wise
(C) EMD Column + Row wise (D) EMD Average

The Highlighted part are the segmented region observed from the image



A



B

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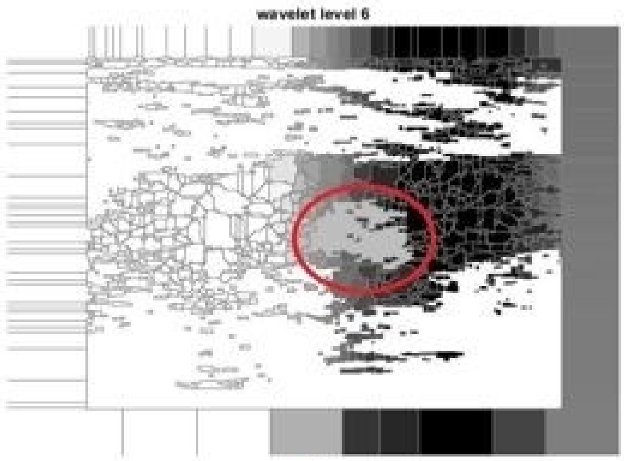

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FIGURE 7.8: (A) Wavelet Level 2 (B) Wavelet Level 4
(C) Wavelet Level 6

The Highlighted part are the segmented region observed from the image

The Equation to find the PSNR and MSE of the images are:

$$MSE = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\left|U[m,n] - F[m,n]\right|^2 \qquad \ldots\ \ldots\ \ldots\ \ldots(6)$$

$$\text{PSNR (db)} = 10\log10\{255^2/\text{MSE}\} \qquad \ldots\ \ldots\ \ldots\ \ldots(7)$$

Here M and N are the Row and Column Vectors

.

TABLE 7.1: PSNR Values of the Segmented Images

2nd Iteration	6th Iteration	Imf 1	EMD Row wise	EMD Column wise	EMD Row + Column	EMD Avg.	Haar level 8	Dabeauche level 4
102.45db	106.55db	95.5db	96.6db	98db	98.5 db	97.89db	94.578db	98.45db

Chapter 8

Future Work and Conclusion

• If we log compress the image then speckle noise transformed into AWGN. Then by using user defined wavelet transformation we can filter out the noises properly which follows the Gaussian distribution.

• Image can be properly segmented by using a proper watershed algorithm such as watershed, seed growing method, entropy modeling etc.

• For signal and image DE noising there are some filter available (Lee, Frost, Kaun, Gamma MAP.) We want to use that and then apply EMD.

• EMD itself is subdivided in some categories such as EEMD, BEMD. We want to apply these algorithms and observe its effect.

• The other speckle reduction techniques such as SRAD (Speckle reduction using anisotropic diffusion) and WAVELET transform are not perfect. We could apply different types of EMD (such as BEMD, EEMD) to enhance their efficiency.

• Also to observe their result we are using different segmentation techniques such as cell based segmentation, watershed and also seed growing method. After careful deduction we have observed that the combination of wavelet along with EMD gives us the better result in segmentation.

• The initial image can be preprocessed by using many used defined filter and we can apply that to reduce the image noise.

Bibliography

[1] Garcia, M., Jemal, A., Ward, E., Center, M., Hao, Y., Siegel, R., and Thun, M., "Global Cancer Facts & Figures 2007", *A*merican Cancer Society, 2007.

[2] American Cancer Society, Cancer Facts & Figures 2008 "American Cancer Society ", *2*008.

[3] American Cancer Society, Cancer Facts & Figures 2008 "American Cancer Society ", *2*009.

[4] Network of Strength. "Breast Cancer Statistics. ", *2*009.

[5] Network of Strength. Breast Cancer Statistics. 2009. "http:// www.networkofstrength.org/ information/ bcnews/ stats.php", . Jan. 2010.

[6] Cheng, H.D., Cai, X., Chen, X., Hu, L., and Lou, X. "Computer-aided detection and classification of micro calcifications in mammograms: a survey. ", *P*attern Recognition 36,12 (2003), 2967-2991.

[7] American Cancer Society. What Are the Key Statistics for Breast Cancer? 2009. "http:// www.cancer.org/docroot/cri/content/ cri241x.what.are.the.key. statistics.for. breast.cancer.5.asp. ", *J*an. 2010.

[8] S.J.Nass, I.C. Henderson, and J.C. Lashof, Eds "Committee on Technologies for the Early Detection of Breast Cancer, Mammography and Beyond: Developing Technologies for the Early Detection of Breast Cancer, ", *N*ational Cancer Policy Board, Institute o f Medicine, and Commission on Life Studies, National Research Council, 2001.

[9] Xu Liu, Zhimin Huo and Jiwu Zhang. "Automated segmentation of breast lesions in ultrasound images. Proceedings of the 2005 IEEE Engineering in Medicine and Biology, ", *2*7th Annual Conference Shanghai, China, September 1-4, 2005.

[10] E. J. Bond, X. Li, S. C. Hagness, B.D. Van Veen, "Microwave Imaging via Space-Time Beamforming for Early Detection of Breast Cancer, ", *I*EEE Trans. Ant. Propag., vol. 51,no. 8, Aug. 2003.

[11] X. Li and S.C. Hagness, "A confocal microwave imaging algorithm for breast cancer detection, ", *I*EEE Microwave Wireless Components Lett., vol. 11, pp. 130-32,Mar.2001.

[12] S.C. Hagness, A. Taflove, and J.E. Bridges, "Two-dimensional FDTD analysis of a pulsed microwave confocal system for breast cancer detection: fixed-focus and antenna-array sensors", *I*EEE Trans Biomed Eng, vol. 45, pp. 1470.1479, Dec. 1998

[13] Roger Gent, Frederick Kremkau "BASIC PHYSICAL PRINCIPLES OF ULTRASOUND ", *A*pplied Physics and Technology of Diagnostic Ultrasound;

[14] Jens E. Wilhjelm, Andreas Illum, Martin Kristensson and Ole Trier Andersen "Medical diagnostic ultrasound- physical principles and imaging ", *B*iomedical Engineering, DTU Elektro ,Technical University of Denmark, (Ver. 3.1, 2 October 2013) © 2001-2013 by J. E. Wilhjelm

[15] H. H. Arsenault and G. April, "Properties of speckle integrated with a finite aperture and logarithmically transformed", *L*aboratoire de Recherches en Optique et Laser, Departement de Physique, Universitg Laval, Quebec, Canada, GIK 7P4 (Received 19 April 1976).

[16] Richard N. Czerwinski, "Detection of Lines and Boundaries in Speckle Images—Application to Medical Ultrasound", *D*etection of Lines and Boundaries in Speckle Images—Application to Medical Ultrasound

[17] Karl Krissian "Oriented Speckle Reducing Anisotropic Diffusion ", *M*ember, IEEE,Carl-Fredrik Westin, Member, IEEE,Ron Kikinis, and Kirby Vosburgh, Member, IEEE.

[18] Network of Strength. "Reduction of Speckle Noise and Image Enhancement of Images Using Filtering Technique ", *2*009.

[19] Milindkumar V. Sarode, Prashant R. Deshmukh "http:// www.networkofstrength.org/ information/ bcnews/ stats.php", . International Journal of Advancements in Technology http://ijict.org/ ISSN 0976-4860 Vol 2, No 1 (January 2011)

[20] Cheng, H.D., Cai, X., Chen, X., Hu, L., and Lou, X. "Computer-aided detection and classification of micro calcifications in mammograms: a survey. ", *P*attern Recognition 36,12 (2003), 2967-2991.

[21] Wen-Chun Shih "Time Frequency Analysis and Wavelet Transform Tutorial Wavelet for Music Signal Analysis ", *G*raduate Institute of Communication Engineering National Taiwan University, Taipei, Taiwan, ROC

[22] C. Valens, "A Really Friendly Guide to Wavelets, ", *P*reprint, 1996. IEEE Press, 1997.

[23] UDOMCHAI TECHAVIPOO and TOMY VARGHESE "WAVELET DENOISING OF DISPLACEMENT ESTIMATES IN ELASTOGRAPHY ", *U*ltrasound in Med. & Biol., Vol. 30, No. 4, pp. 477– 491, 2004

[24] Yao Pei, Yangang Wu, Dacheng Jia "Image Denoising based on Bidimensional Empirical Mode Decomposition, ", *2*011 International Conference on Mechatronic Science, Electric Engineering and Computer August 19-22, 2011, Jilin, China

[25] Abdel-Ouahab Boudraa,Senior Member, IEEE, and Jean-Christophe Cexus "EMD-Based Signal Filtering, ", *I*EEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 56, NO. 6, DECEMBER 2007.

[26] Somayeh Bakhtiari, Sos Agaian and Mo Jamshidi "Integrating Ensemble Empirical Mode Decomposition and Nonlinear Anisotropic Diffusion Filter for Speckle Noise Reduction in Underwater Sonar Images ", *I*mage Processing: Algorithms and Systems IX, edited by Jaakko T. Astola, Karen O. Egiazarian, Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 7870, 78701C · © 2011 SPIE-IS&T

[27] Xiang Zhou,Adrian Gh. Podoleanu, Zhuangqun Yang, Tao Yang, and Hong Zhao "Morphological operation-based bi-dimensional empirical mode decomposition for automatic background removal of fringe patterns ", *R*eceived 20 Jul 2012; revised 27 Aug 2012; accepted 9 Sep 2012; published 8 Oct 2012 (C) 2012 OSA 22 October 2012 / Vol. 20, No. 22

[28] INTERNET "http:/ /therapeuticdynamics.com /our-services-2/ what-are-modalities ", *W*EB ADDRESS