Sudan University of Science and Technology

College of Graduate studies

Biomedical engineering department

Speckle Noise Reduction Technique in medical Ultrasound Images Based on wavelet Thresholiding

تقليل ضوضاء الرقطة في اجهزةالموجات فوق الصوتيه الطبية باستخدام هجين التقنيه المبني علي مويجات الارتجاع

A Thesis Submitted in Partial Fulfillment for Requirement of the Degree of Master (MSc) in Biomedical Engineering

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2017

بسم الله الرحمن الرحيم

DEDICATION

To my father and mother

For endless love, support and prayers.

To my husband for his support me

To my sisters and brother

To my beloved son (eyed) and daughter (jood)

To my university

To my teachers and all who taught me a letter

To my best friends and Colleagues.

To all those whom I love

I dedicate this work hoping that it will be of some benefit…….

ACKNOWLEDGEMENT

This thesis would not have been possible without the contribution of many people. I regret it is not possible to name them all.

Particularly, I am extremely indebted to Dr. Zeinab Adam Mustafa for her continuous help and fruitful supervision, and I cannot find words to express to Dr. Zeinab for her unlimited support, suggestions, motivation and encouragement.

Sincere thanks must also go to the staff of my Colleagues in Sudan University of Science and Technology.

I would like to thank all those who participated in taking this research out to light by data entry and printing.

Above and before all, thanks to Allah who has me the will and ability to fulfil this work.

ABSTRACT

Today, ultrasound (us) is one of the most widely used imaging technologies in medicine .it is portable, free of radiation risk, and relatively inexpensive when compared with other imaging modalities. The ultrasound (us) b-scan images are obtained with simple linear or sector scan us probe, which show a granular appearance called speckle .this noise lead to the target delectability and recongnition and pathological tissue.

The objective of this thesis is to give an overview about types of reduction techniques in ultrasound imaging, and to carry out comparative evaluation of despeckle filtering.

Based on image quality evaluation matrix a new speckle suppression methods and coherence enhancement of medical ultrasound images were propsed.combines TV and wavelet decommmssion, it has been found the quality evaluation matrix the proposed method performs better than all other method while still retaining the structural details and experimental results show that this method retains the edge.

المستخلص

الموجات فوق الصوتيه تعتبر واحده من تقنيات التصويرالاكثراستخداما علي نطاق واسع في التصويرالطبي .وهي اجهزه خاليه من الخطر الاشعاعي,وغير مكلفه نسبيا مقارنة مع طرق التصوير الاخرى.

في الموجات فوق الصوتيه يتم الحصول علي الصوره بالماسح الضوئي مع وجود خطا بسيط,والذي يظهر بمظهر حبيبات تسمي الرقطه.وهذه الضوضاء تقود الي تقليل التباين والدقه التي توثرعلي قدره الانسان علي تحديد الانسجه الطبيعيه من المريضه .

الهدف من البحث هو اعطاء لمحه عامه عن انواع التقنيات التي تساعد علي ازالة الرقطه في صور الموجات فوق الصوتيه .ولاجراء تقييم التقنيات علي اساس مقايسس تقييم جوده الصوره.

واقتراح اسلوب جديد لازالة الرقطه وتعزيز تماسك صور الموجات فوق الصوتيه الطبية ,وذلك بالجمع بين مرشحي Total Variation و Wavelet

وقد وجد ان الطريقة المقترحة تنفذ مقاييس تقييم الجوده افضل من كل الوسائل الاخرى والنتائج التجريبيه تبين ان هذا الاسلوب يحتفظ بالحواف والقوام جيدا اثناء ازاله الرقطه.

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LIST OF Abbreviation

US	Ultrasound
RF	Radio Frequency
SAR	Synthetic aperture radar
SPECT	Signal photon emission computer tomography
MRI	Magnetic resonance imaging
CT	Computed Tomography
2D	Two-dimensional
3D	Three dimensional
PET	Positron emission tomography
Q	Image quality measure.
PDE	Partial Differential Equation
SNR	Signal to Noise Ratio
MSE	Mean Square Error
PSNR	Peak signal to noise ratio
SSIM	Structural similarity index method
DsFwiener	First-order statistics filtering
DsFCa	Linear scaling filter
SRAD	Speckle reducing anisotropic diffusion
DsFgf4d	Geometric despeckle filter
DsFwavelet	Wavelet despeckle filter

DsFmedian	Median despeckle filter
A-mode	Amplitude mode
TV	Total Variation
1D	One Dimensional
B-mode	Brightness mode
CWT	Continuous Wavelet Transform
DWT	Discrete Wavelet Transform

LIST OF SYMBOLS

ai, j Additive noise component on pixel *i*, JSpeckle index

C Speckle index

Δf Frequency shift (Doppler frequency shift)

f Frequency of ultrasound wave

f_0 Transmitted frequency of ultrasound signal

$g_{i,j}$ Observed ultrasound signal in discrete formulation after logarithmic compression

*g*max Maximum gray-level values in a pixel neighborhood

λ Wavelength of ultrasound wave

m/s and cm/s Meters per second and centimeters per second

μ Mean

$n_{i,j}$ Multiplicative noise component (independent of *gi*, *j* , with mean 0) on pixel *i*, *j*

$nl_{i,j}$ Multiplicative noise component after logarithmic compression onpixel *i*, *j*

σ Standard deviation

بسم الله الرحمن الرحيم

CHAPTER ONE

INTRODUCTION

1.1introduction:-

In the last few decades research within the space of medical imaging system has made many alternative ways for clinical check-up, These techniques have revolutionized diagnostic radiology, providing the clinician with new information about the interior of the human body that has never been available before. Like CT scan, and SPECT ultrasound, and other; all with its own a execs and cons. Above all, ultrasound imaging which is a popular vital tool for diagnosis, it provides in non-invasive manner the internal structure of the body to detect eventually diseases or abnormalities tissues. And it's one of the most widely used medical imaging procedure because it has several advantages over other medical imaging modalities is economical, comparatively safe, and easily portable and 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 which is very useful for intensive care unit patients. Ultrasound provides detailed imaging of soft tissues that is usually obscured in X-ray images. Unlike other tomographic techniques, ultrasound imaging offers interactive visualization of the underlying anatomy in real time. Since it does not use ionizing radiation, ultrasound yields no risks to the patient, and continuing improvement in image quality. The main weakness of medical image modalities corrupted by different kinds of noise in its acquisition and transmission or processing. Can cause signal and image exhibit distinct types of degradation. The usefulness in ultrasound imaging degraded by the presence of signal dependent noise known as speckle. it's a particular type of noise and it's a random, and multiplicative in nature and an inherent property of medical ultrasound imaging, It arises from the constructive and destructive interference of ultrasound scattered from very small structures within a tissue It has negative impact on ultrasound imaging, and radical reduction in contrast resolution may be responsible for the poor effective resolution of ultrasound image,And thus demean the accuracy and quality of the image, and affect human interpretation. Poor image quality often makes feature extraction, analysis, recognition, and quantitative measurements problematic and unreliable. Therefore, Speckle reduction is very important and critical for ultrasound imaging.

Image denoising can be considered as a preprocessing step or as a complete process. In the first case, the image denoising is used to improve the accuracy of various image processing algorithms such as registration or segmentation. Then, the quality of the artifact correction influences performance of the procedure. In the second case, the noise removal aims to improving the image quality for visual inspection. The preservation of relevant image information is important, especially in a medical context. An appropriate method for speckle reduction is one which enhances the signal-to noise ratio while conserving the edges, fine details and lines in the image [1,2].

1.2 Problem Statement:-

In medical image processing, it is very vital to obtain exact images to facilitate accurate explanation for the known request. Low image quality is an obstacle for effective feature extraction, analysis, recognition and quantitative measurements. Therefore, there is a fundamental need of noise reduction from medical images.

Speckle is multiplicative noise that gets multiplied with the ultrasound signal during capture, transmission, or processing so it contains information about the density and the size of scatters but still considered as noise because its presence spoils medical image analysis procedures. And it is a random and deterministic in an image and it has negative impact on ultrasound imaging, Radical reduction in contrast resolution may be responsible for the poor effective resolution of ultrasound. Image denoising is a very important task, it’s a fundamental process need of removing noise in the images, and speckle reduction is very important and critical for ultrasound imaging

One challenging problem in ultrasound imaging is denoising since the signal-to-noise ratio is low, and it requires specific filters due to the statistical nature of the speckle.

1.3 Objectives:-

General objective:-

The aim of the research to improve the ultrasound image quality and the analysis ability by propose a new scheme to reduction noise and artifacts in the image while saving the image information.

Specific objective:-

- Study about types of speckle reduction techniques in ultrasound imaging.
- To carry out a comparative evaluation of despeckling filtering based on image quality evaluation metrics.

- To resolve the contradiction between speckle noise suppression and texture and edges image preserving, which cannot be resolved by the TV- based method or wavelet method independently.

1.4 Research layout:-

The layout of this thesis consists of six chapters there are: chapter one include an introduction view of the research, problem statement, objectives and significant of the study, while chapter two involve theoretical background about the ultrasound imaging and the noise interfere with it. literature review in chapter three, in chapter four is a comparative evaluation between number of filters that work in speckle reduction depending on the Image quality evaluation matrix and Structural similarity index method, however in chapter five the proposed technique along with its evaluation and the results are compared with some existing techniques to prove its worth were described, finally the conclusion and future work to be done in chapter six.

CHAPTER TWO
THEORETICAL BACKGROUND

2.1. A Brief Review of Ultrasound imaging:

Medical imaging technology has experienced a dramatic change in the last 30 years. Previously, only X-ray radiographs were available, which showed the organs as shadows on a photographic film. With the advent of modern computers and digital imaging technology, new imaging modalities like computer tomography (CT or computer-assisted tomography), magnetic resonance imaging (MRI), positron emission tomography (PET), and US, which deliver cross-sectional Images of a patient's anatomy and physiology have been developed. Among the imaging techniques employed are X-ray angiography, X-ray, CT, ultrasound imaging, MRI, PET, and single photon emission computer tomography. MRI and CT have advantages over ultrasound imaging in the sense that higher resolution and clearer images are produced [3].The use of ultrasound in the diagnosis and the assessment of imaging organs and soft tissue structures, as well as human blood, Because of its noninvasive nature and continuing improvements in imaging quality, ultrasound imaging is progressively achieving an important role in the assessment and the characterization of cardiac imaging, and the assessment of carotid artery disease. The main disadvantage of ultrasound is that it does not work well in the presence of bone or gas, and the operator needs a high level of skill in both image acquisition and interpretation to carry out the clinical evaluation.

On the other hand, standard angiography cannot give reliable information on the cross-sectional structure of the arteries. [3]

2.2 Waves and sound wave:-

There are two types of waves: Transverse waves: these waves are perpendicular to the direction of energy transfer, e.g., violin string .Longitudinal waves: these waves are parallel to the direction of energy transfer, e.g., a pulse from a piston in a cylinder, sound waves. [4]

Sound wave propagates by longitudinal motion (compression/expansion) but not transverse motion (side-to-side) can be modeled as weights connected by springs. [5]

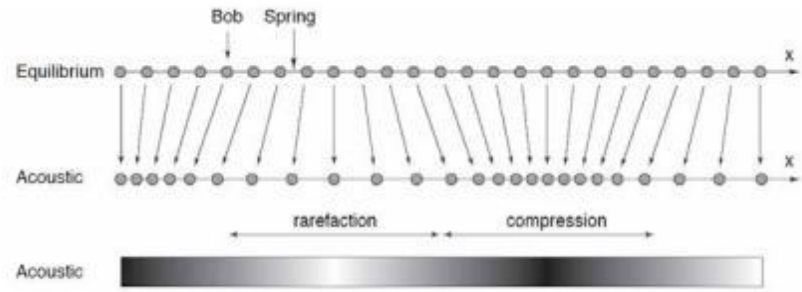


Figure2.1: Sound wave propagate [4]

The measuring of longitudinal waves in two ways Distance: the wave length Frequency: how many times per second the compression peak occurs at a point in space. Frequency (**f**) and wavelength (**λ**) are related by the speed of sound in the medium: $V = f \lambda$ Generally speaking, V is related to the compressibility of the medium, slower in gasses, faster in liquids, and fastest in solids.

And the sound divided into:-

- Infrasound (subsonic) below 20Hz,
- Audible sound 20-20,000Hz and
- Ultrasound above 20,000HzNon-diagnostic
- ,medical applications <1MHz and Medical diagnostic ultrasound >1MH.[6]

2.3 Nature of Ultrasound:-

Ultrasound is a mechanical wave, with frequencies that higher than the upper limit for audible human hearing (greater than 20 kHz), and a frequency that used for clinical between 1 and 15 MHz And

The speed of sound in tissue is 1540 m/s.

Medical diagnostic ultrasound imaging is performed using a pulse-echo technique. The Probe is placed on the skin surface, and a transducer in the probe transmits small pulses of ultrasound. The transducer (transmitter) works on the piezoelectric principle, and converts electrical energy to mechanical energy. The same transducer can be used to receive the returning echoes (receiver).

2.4 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 echo that travels back to the transducer and thus gives 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 (spreading) can be thought of, when one shines strong light on the tip of a needle: light is scattered in all directions [7]. 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.

Specifically, reflection is taking place when the interface is large relative to the wavelength (e.g. between blood and intimate 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 into intensity of the forward propagating acoustic pulse due to reflection, refraction, scattering and absorption is under one named attenuation. [6]

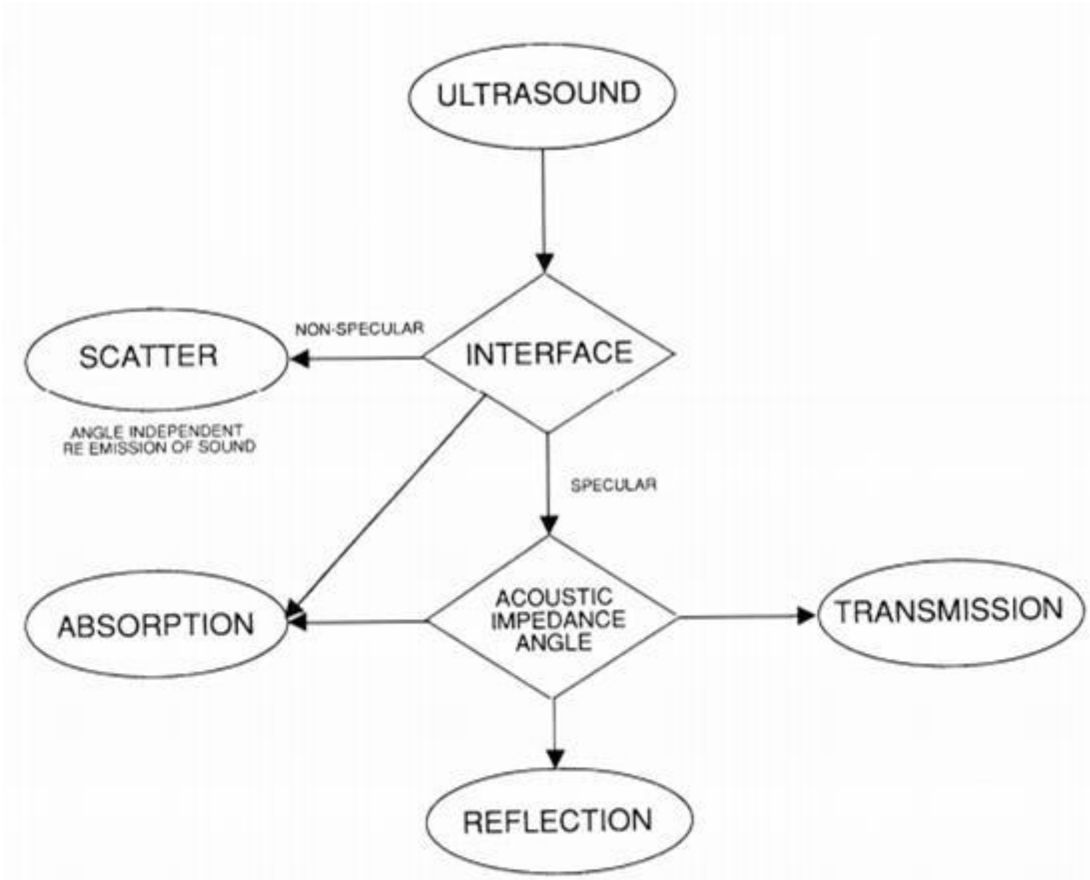


Figure2.2: Interaction of Ultrasound with Tissue [4]

2.5 Ultrasound Imaging &Instrumentation:-

In ultrasound imaging, the transducer is the main part of the ultrasound machine which generates and sends the sound waves and receives the echoes throw a principle called the piezoelectric effect, the probe also has a sound absorbing substance to eliminate back reflections from the probe itself and acoustic lens to focus the emitted sound waves. And the probe comes in many shapes and size that determines its field of view and the frequency of the sound wave determine the resolution of the image. Proper selection of transducer frequency is an important concept for providing optimal image resolution in diagnostic and procedural US, because when the ultrasound waves have high- of the echo frequency (short wavelength) then the high axial resolution images was generated images. The time of arrival of the echo from a given interface depends on its depth. The ultrasound system computes the depth using the time of echo arrivals after the transmission. The brightness of the echo on the display is determined by the amplitude.

2.5.1Ultrasound Modes:-

The various modes show the returning echoes in different ways. And the two main scanning modes are A- and B-modes. Other modes used are M-mode, duplex ultrasound, color-coded ultrasound, and power Doppler ultrasound, which will be briefly introduced below.

A-mode refers to amplitude mode scanning, which is mainly of historical interest. In this mode, the strength of the detected echo signal is measured and displayed as a continuous signal in one direction. A-mode is a line, with strong reflections being represented as an increase in the signal amplitude. This scanning technique has the limitation that the recorded signal is 1D with limited anatomical information. A-mode is no longer used, especially for the assessment of cardiovascular disease. Its use is restricted to very special uses such as in ophthalmology to perform very accurate measurements of distance.

B-mode refers to the brightness mode. In B-mode, echoes are displayed as a 2D grayscale image. The amplitude of the returning echoes is represented as dots (pixels) of an image with different gray values. The image is constructed by these pixels line by line. Advances in B-mode ultrasound have resulted in improved anatomic definition, which has enabled plaque characterization [8, 9].

(M) Mode (also sometimes referred to as TM-scan) is a way to display motion, scanning acquires a continuous series of A-mode lines and displays them as a function of time. The brightness of the displayed M-mode signal represents the amplitude of the backscattered echo. And it mode is used in cardiology.

Doppler techniques use the Doppler Effect as a further source of information: if the ultrasound waves are reflected by an interface moving towards the transducer or away from it, the reflected frequency will be higher or lower respectively than the transmitted frequency. The difference between the emitted and received frequencies is proportional to the speed of the moving reflector. This phenomenon is called the Doppler Effect, and the difference is called the Doppler frequency or Doppler shift. A Doppler frequency shift in the reflected sound from insolated red blood cells, And this frequency shift can be used to calculate the velocity of the moving blood using the Doppler equation Doppler can be used to demonstrate the blood flow in the peripheral vessels of adults.

2.5.2 Instrumentation:-

A block diagram of the basic instrumentation used for ultrasound imaging is shown in Figure (2.3). The input signal to the transducer comes from a frequency generator. The frequency generator is gated on for short time durations and then gated off, thus providing short periodic voltage pulses.

These pulsed voltage signals are amplified and fed via transmit/receive switch to the transducer. Since the transducer (which work as transmitter and receiver) transmits both high power pulses and also receives low intensity signals, the transmit and receive circuits must be very well isolated from each other. The transmit/receive switch serves this purpose. The amplified voltage is converted by the transducer into mechanical pressure wave which is transmitted into the body. Reflection and scattering from boundaries and structures within a tissue occur.

The backscattered pressure waves reach the transducer at different times dictated by the depth in tissue from which they originate, and are converted into voltage by the transducer. These voltages have relatively small values, and so pass through a very low-noise preamplifier before being digitized. Time gain compensation is used to reduce the dynamic range of the signals, and after appropriate amplification and signal processing, the images are displayed in real time on the computer monitor.

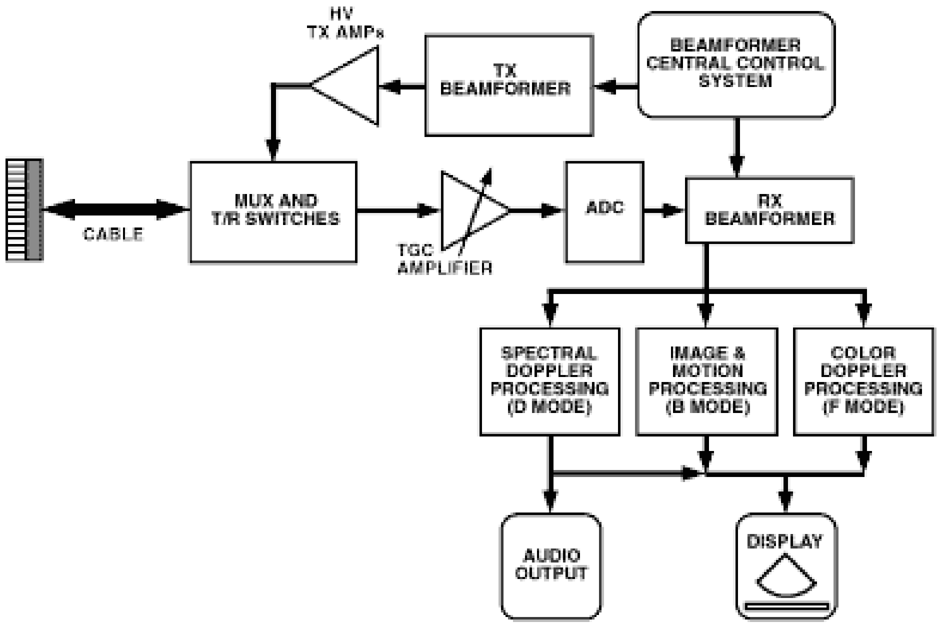


Figure 2.3: Block diagram of Ultrasound Imaging System [10]

2.6 Image Quality and Resolution:-

The quality of the produced ultrasound image depends on the image Resolution, Resolution is defined as the smallest distance between two features such that the features can be individually resolved. It's the ability to distinguish two close objects as separate, is very important in ultrasound. There are two types of resolution – axial and lateral.

- **Axial resolution:** is the ability to distinguish two objects that lie in a plane parallel to the direction of the ultrasound beam. Axial resolution is equal to half of the pulse length. Higher frequency probes have shorter pulse lengths, which allows for better axial resolution [11].
- **Lateral resolution**:-is the ability to distinguish two objects that lie in a plane perpendicular to the direction of the ultrasound beam. Lateral resolution is related to the ultrasound beam width, the more narrow

(focused) the ultrasound beam width, the greater the lateral resolution. High frequency probes have narrower beam widths, which allows for better lateral resolution. Poor lateral resolution means that two objects lying side by side may be seen as one object [11].

2.7 Noise in an Image:-

The common problem suffer in medical imaging system is noise, it is mean that is an undesirable signal or data which can corrupt the real signals and reduce the size of object, and blurring of edges in an image .and the noise in digital images obtain during image acquisition or transmission process or even during reproduction of the image.

It is generally desirable for image brightness (or film density) to be uniform except where it changes to form an image. When no image detail is instant that mean the variation is produced by some factors. This random variation in image brightness is designated as noise it reduces image quality and is especially significant when the objects being imaged are small and have relatively low contrast.

They are four important classes of noise encountered in digital images are additive noise, impulse noise, quantization noise and multiplicative.

Additive Noise: Sometimes the noise generated from sensor is thermal white Gaussian, which is essentially additive and signal independent and it is represented as in Equation (2.1).

$$G(I, j) = f(I,j) + a(I,j) \quad (2.1)$$

Where g (I, j) is the result of the original image function f(I,j)corrupted by the additive Gaussian noise a(I,j).

Impulse Noise: Quite often the noisy sensors generate impulse noise.

Sometimes the noise generated from digital image transmission system is impulsive in nature, which can be modeled as in Equation (2.2)

$$g(I,j)=(1-p)f(I,j)+p.imp(I,j) \qquad (2.2)$$

Where imp (I,j)is the impulse noise and p is a binary parameter that assumes the values of either 0 or 1. The impulse noise is also known as salt and pepper noise.

Quantization Noise: The quantization noise is a signal dependent noise and is characterized by the size of quantization interval. It produces image like artifacts and may produce false contours around the objects. The quantization noise removes the image details which are of low contrast.

Multiplicative Noise: The graininess noise from photographic plates is Multiplicative in nature. Speckle noise occurs in coherent imaging systems such as LASER, SAR and ultrasound imaging is also multiplicative in nature, which may be modeled as in Equation (2.3)

$$G(I, j) = f(I, j)*m(I, j) \qquad (2.3)$$

Where m (I, j) is the multiplicative noise. It is a signal dependent noise whose magnitude is related to the value of the original pixel.

Speckle noise is difficult to reduce, since it is multiplicative and signal dependent in nature. This study aims to reduce the system noise artifact speckle in ultrasound images.

2.8 Speckle Noise:-

Different image modalities exhibit distinct types of degradation. Images formed with coherent energy, such as ultrasound, suffer from speckle noise. Image degradation can have a significant impact on image quality and, thus, affect human interpretation and the accuracy of computer-assisted methods. Poor image quality often makes feature extraction, analysis, recognition, and quantitative measurements problematic and unreliable. The use of ultrasound in the diagnosis and the assessment of arterial disease is well established because of its noninvasive nature, its low cost, and the continuing improvements in image quality [12]. Speckle is a form of locally correlated multiplicative noise that corrupts medical ultrasound imaging making visual observation difficult [8].The presence of speckle noise in ultrasound images has been documented since the early 1970s, where researchers such as Wagneret al. [8], and Goodman [9] described the fundamentals and the statistical properties of the speckle noise. Speckle is not truly noise in the typical engineering sense since its texture often carries useful information about the image being viewed [8, 9]. Speckle noise is the primary factor that limits the contrast resolution in diagnostic ultrasound imaging, thereby limiting the delectability of small low-contrast lesions and making the ultrasound images generally difficult for the no specialist to interpret [8, 13, 14]. Because of the speckle presence, ultrasound experts with sufficient experience may not often draw useful conclusions from the images [14].

Speckle also limits the effective application (e.g., edge detection) of automated computer-aided analysis (e.g., volume rendering, 3D display) algorithms. It is caused by the interference between ultrasound waves reflected from microscopic scattering through the tissue. Therefore, speckle is most often considered a dominant source of noise in ultrasound imaging and should be filtered out [13, 14] without affecting important features of the image. In this book, we carry out a comparative image quality evaluation metrics, as well as visual assessment by experts on 440 ultrasound images of the carotid artery bifurcation. Moreover, a comparative evaluation framework for the selection of the most appropriate despeckle filter for the problem under investigation is proposed. Evaluation of despeckle filtering techniques based on texture analysis,

2.9 Physical Properties and the Pattern of Speckle Noise

The speckle pattern, which is visible as the typical light, and dark spots the image is composed of, results from destructive interference of ultrasound waves scattered from different sites. The nature of speckle has been a major subject of investigation. When a fixed rigid object is scanned twice under exactly the same conditions, one obtains identical speckle patterns. Although of random appearance, speckle is not random in the same sense as electrical noise. However, if the same object is scanned under slightly different conditions, say, with a different transducer aperture, pulse length, or transducer angulations, the speckle patterns change. [3]

The most popular model adopted in the literature to explain the effects that occur when a tissue is insinuated is illustrated in Figure (2.4) where a tissue may be modeled as a sound absorbing medium containing scatters, which scatter the sound waves. These scatters arise from in homogeneity and structures approximately equal to or smaller in size than the wavelength of the ultrasound, such as tissue parenchyma, where there are changes in acoustic impedance over a microscopic level within the tissue. Tissue particles that are relatively small in relation to the wavelength (i.e., blood cells), and particles with differing impedance that lie very close to one another, cause scattering or speckling..

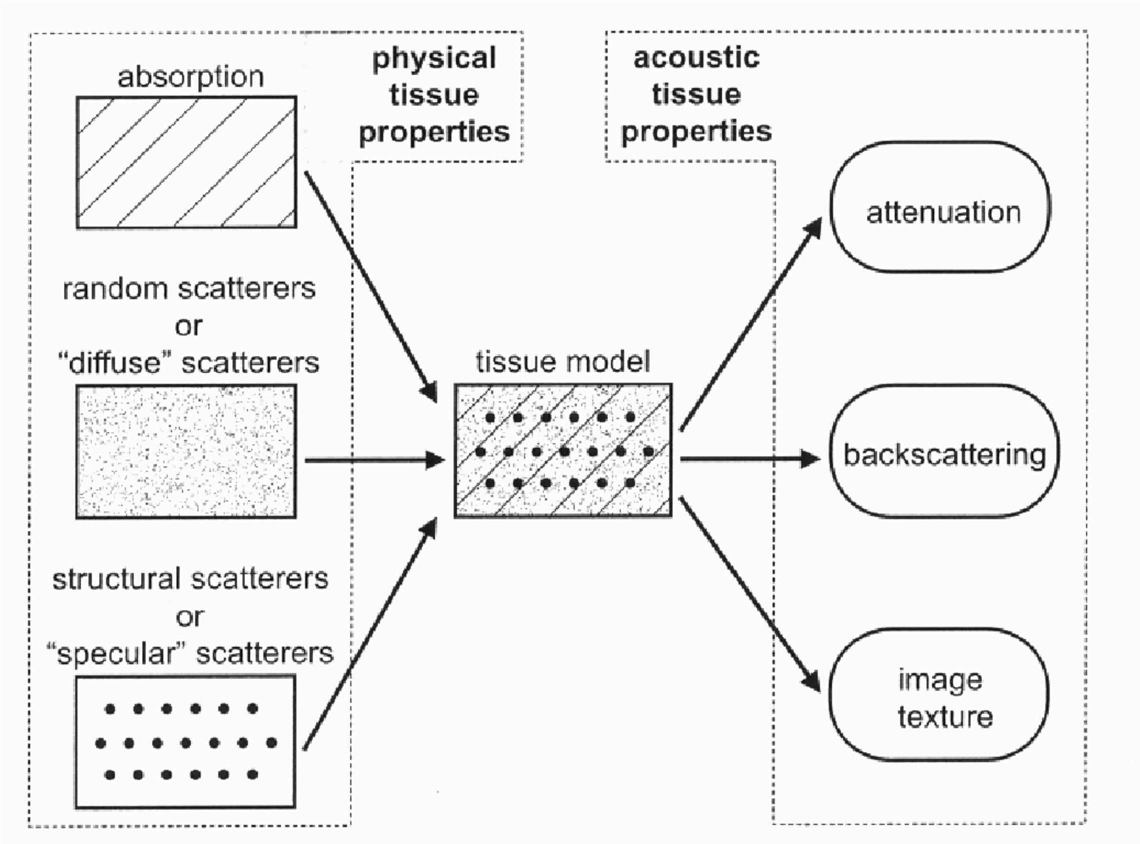


figure2:4 the usual tissue model in ultrasound imaging (modified from Ref.[15]

Absorption of the ultrasound tissue is an additional factor to scattering and refraction, responsible for pulse energy loss. The process of energy loss involving absorption, reflection, and scattering is referred to as attenuation, which increases with depth and frequency. Because a higher frequency of ultrasound results in increased absorption, the consequence is a decrease in the depth of visualization [16].

The nature of the 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:

- ❖ 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 [17].

2.10 Need for Despeckling:-

Speckle is considered as the essential source of noise in ultrasound imaging and should be processed without affecting important image features, certain speckle diagnostic information and should be retained.

The main purposes for speckle reduction in medical ultrasound imaging are:

1. To enhance the human interpretation of ultrasound images – speckle reduction makes an ultrasound image cleaner with clearer boundaries

2. Despeckling is a preprocess step for many ultrasound image processing tasks such as segmentation and registration – speckle reduction improves the speed and accuracy of automatic and semiautomatic segmentation & registration [16].

2.11Speckle Noise Reduction:-

Generally, speckle noise can be reduced by spatial filtering which is usually done during data acquisition stage; speckle reduction by spatial filtering is performed on the image after it is acquired. No matter which method is used to reduce the effect of speckle noise, the ideal speckle reduction method preserves radiometric information, the edges between different areas and spatial signal variability, i.e., textural information.

The spatial filters are categorized into two different groups:

- Non-adaptive: These types of filters take the parameters of the whole image signal into consideration and leave out the local properties of the terrain backscatter or the nature of the sensor. These kinds of filters are not appropriate for non-stationary scene signal. Fast Fourier Transform (FFT) is an example of such filters.
- Adaptive filters: These filters accommodate changes in local properties of the terrain backscatter as well as the nature of the sensor. In these types of filters, the speckle noise is considered as being stationary but the changes in the mean backscatters due to changes in the type of target are taken into consideration. Adaptive filters reduce speckles while preserving the edges (sharp contrast variation).

2.12 Speckle Noise Modeling:-

In ultrasound images, the noise content is multiplicative and non Gaussian. Such noise is generally more difficult to remove than additive noise, because the intensity of the noise varies with the image intensity. [3]

A model of multiplicative noise is given by

$yij = Xijni$ (1)

where the speckle image yij is the product of the original image Xij, and the non-Gaussian noise

nij. The indices i, j represent the spatial position over the image. In most applications involving multiplicative noise, the noise content is assumed to be stationary with unitary mean and unknown noise variance σ2. To convert multiplicative noise into an additive noise, as given in the Eq.(2), a logarithmic transformation is applied to the speckle image yij [7]. The noise component nij is then approximated as an additive zero means Gaussian noise.

$\ln yij = \ln Xij + \ln nij$ (2)

CHAPTER THREE
LITERATURE REVIEW

In the last few decades, several non-invasive new imaging techniques have been discovered such as CT scan, SPECT, ultrasound, digital radiography, magnetic resonance imaging (MRI), spectroscopy and others. These techniques have revolutionized diagnostic radiology, providing the clinician with new information about the interior of the human body that has never been available before. Among these imaging techniques, Ultrasound imaging is an incontestable vital tool for diagnosis, it provides in non-invasive manner the internal structure of the body to detect eventually diseases or abnormalities tissues. Unfortunately, the presence of speckle noise in these images affects edges and fine details which limit the contrast resolution and make diagnostic more difficult.

With the advancement in image technology, image de noising has found renewed interest for researchers. Image de noising is one of the fundamental challenges in the field of image processing, where the main goal is to remove the noise from an image while retaining as much as possible the important signal features of an images, A lot of papers discussed noise reduction in medical ultrasound images, One of these papers (Speckle Noise Reduction in Medical Ultrasound Images) (F.Benzarti & Amiri 2012), This paper presented that existence of speckle noise in the ultrasound image is undesirable since it disgrace image quality by affecting edges and local details between heterogeneous organs ,Which are the most interesting part for diagnostics. They have been proposed a de noising approach which combines homomorphic transformation and diffusion tensors. The idea is to allow diffusion along the orientation of greatest coherence under condition of additive noise. However, the effectiveness of the proposed approach relies on the choice of the diffusion weight functions which control the diffusion along the orientation of greatest coherence. The experimental results on a real ultrasound images are very promising in terms of reducing speckle while preserving the appearance of structured regions and organ surface.

Another successful paper (Survey on Medical Image De noising Using various Filters and Wavelet Transform) (S.Khera & S.Malhotra 2014) conclude that Normal filters may work efficiently if the noise level is low but if the noise level is high normal filters would not be able to work efficiently. In such a case, combinations of filters are required to be done to enhance the quality of the image. Wavelet transform is best suited for de noising because of its properties like sparsity, multi-resolution and multi-scale nature. Which wavelet should be applied on noisy image depends upon the nature of the application; Wavelet transform can examine signals in time and frequency domain simultaneously. If any image is decomposed using wavelet, then it has two functions that are wavelet function and scaling function. Wavelet function is used to represent the high frequency component i.e. detail part of an image while scaling function is used to represent the low frequency component i.e. smooth part of an image. Wavelet is a mathematical tool. Data can be set into different frequency component with the help of wavelet and then each component is studied with a resolution matched to its scale. There are several transforms available like Fourier transform, Hilbert transform, Wavelet transform, etc. The wavelet transform is better than Fourier transform because it gives frequency representation of raw signal at any given interval of time,

(Speckle noise reduction of medical ultrasound images using bayesshrink wavelet threshold)K. Karthikeyan and C. Chandrasekar, 9 may 2011. In diagnosis of diseases Ultrasonic devices are frequently used by healthcare professionals. The main problem during diagnosis is the distortion of visual signals obtained which is due to the consequence of the coherent of nature of the wave transmitted. These distortions are termed as ‘Speckle Noise’.

The present study focuses on proposing a technique to reduce speckle noise from ultrasonic devices. This technique uses a hybrid model that combines fourth order PDE based anisotropic diffusion, linked with SRAD filter and wavelet based BayesShrink technique. The proposed filter is compared with traditional filters and existing filters using anisotropic diffusion. Experimental results prove that the proposed method is efficient in reaching convergence quickly and producing quality denoised images.

(A.Vishwa & S.Sharma) in their paper (Speckle Noise Reduction in Ultrasound Images by Wavelet Thresholding) (2012) pointed out to the use of filter in digital image processing to improves the image to a great extent. Mainly in the case of presence of Speckle noise, filtering is very much required in order to improve the diagnostic examination and also to improve the efficiency of post processing techniques like segmentation. In their paper they have been introduced a relatively simple context-based model for adaptive threshold selection within a wavelet de noising framework. Estimations of local weighted variance with appropriately chosen weights are used to adapt the threshold. However, by visual inspection it is evident that the de noised image, while removing a substantial amount of noise, suffers practically node gradation in sharpness and details experimental results show that the proposed method yields significantly improved visual quality as well as better SNR compared to the other techniques in the de noising literature.

TV method and wavelet thresholding were hybridized for speckle
Reduction in ultrasound images (B.Abrahim et al 2012).The noisy image was first decomposed into four sub bands using db8 wavelet. The noise in the low frequency subband LL was eliminated using TV based method and

the wavelet based soft thresholding was applied to the other three sub bands. TV method was used again in the last step to get the denoised image

LAST paper (Speckle Noise Reduction in Ultrasound Images by Wavelet Thresholding based on Weighted Variance) (S.Sudha et al. 2009) discussed speckle noise in ultra sound images and wavelet domain noise filtering, they have been introduced a relatively simple context-based model for adaptive threshold selection within a wavelet thresholding framework. Estimations of local weighted variance with appropriately chosen weights are used to adapt the threshold. The proposed thresholding technique out performs all the standard speckle filters, Weiner filter Visu shrink, and Bayes shrink methods. However, by visual inspection it is evident that the de noised image, while removing a substantial amount of noise, suffers practically no

Degradation in sharpness and details experimental results show that our proposed method yields significantly improved visual quality as well as better SNR compared to the other techniques in the de noising literature.

CHAPTER FOUR

Comparative evaluation of despeckle filtering techniques

Image denoising is often performed on image pixels directly in the spatial-domain or transform-domain throw different size masks [18].

4.1Despeckle Filtering:-Any images formed with coherent energy suffer from speckle noise which is a form of locally correlated multiplicative noise that corrupts medical ultrasound images and makes visual observation difficult. Since the intensity of the noise varies with the image intensity .This type of noise become difficult to remove in medical imaging because it may contain useful diagnostic information so a despeckle filters are prefer to be use in the capture ultrasound image. There are some well known despeckle filtering techniques that can be group under the following categories: linear filtering (local statistics filtering, homogeneity filtering), nonlinear filtering (median filtering, linear scaling filtering, geometric filtering, logarithmic filtering, homomorphic filtering), anisotropic diffusion filtering (anisotropic diffusion, speckle-reducing anisotropic diffusion, coherent nonlinear anisotropic diffusion), and wavelet filtering.

4.1.1 Linear Filtering: The linear filtering technique is based on local statistics that form an output image by computing the central pixel intensity inside a filter moving window (weighted average calculation), which is calculated from the average intensity values of the pixels and a coefficient of variation inside the moving window [19].

4.1.2 Nonlinear filtering:

The nonlinear filtering technique is based on nonlinear operations involving the pixels in a neighborhood, that the pixels values are linearly scaled to despeckle the image [20]. Some of the nonlinear filters are based on the most homogeneous neighborhood around each image pixel [21].

4.1.2.1 Linear Scaling Filter (DsFCa):-

The DsFca filter despeckles the image through linear scaling of the gray-level values [22]. In a window of [5 5] pixels, compute the mean of all pixels whose difference in the gray level with the intensity *gi, j* (the middle pixel in the moving window) is lower than or equal to a given threshold J.Assign this value to the gray level *gi, j.*

With J = a * *g*max. Where *g*max is the maximum gray level of the image and a = [0,1]. Best results can be obtained with a = 0, 1[9]. This filter despeckles the image through linear scaling of the gray-level values in a window and compute the mean of all pixels whose difference in the gray level with the intensity of the middle pixel in the moving window if it is lower than or equal to a given threshold, assign this value to the meddle pixel of the window [15].

4.1.2.2 Geometric filtering (DsFgf4d):-

This filter uses a nonlinear noise reduction technique since it deal with noise as bright and dark edges, so it compares the intensity of the central pixel in a moving window with those of its neighbors, and thus increments or decrements the intensity of the central pixel such that it becomes more representative of its surroundings and preserve the weak edges that need to be preserved [13].

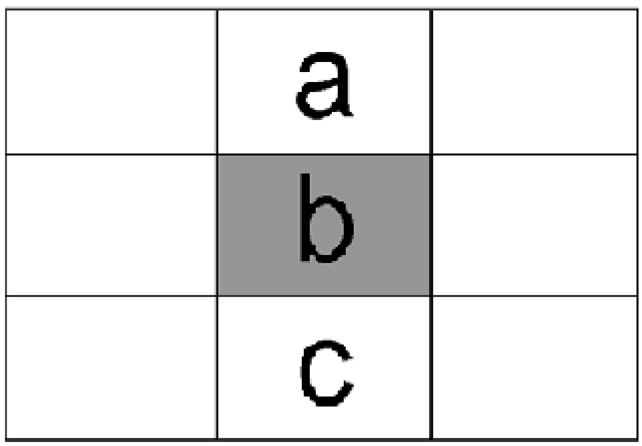


Figure 4.1: The intensity of central pixel b is adjusted based on the values of intensities of pixels a and c.

This is done with respect to the following steps:

- Select the direction and assign the pixel values.
- Carry out central pixel adjustments throw:

if $a \geq b + 2$, then $b = b + 1$;

if $a \cdot b$ and $b \leq c$, then $b = b + 1$;

if $c \cdot b$ and $b \leq a$, then $b = b + 1$;

if $c \geq b + 2$, then $b = b + 1$;

if $a \leq b - 2$, then $b = b - 1$;

if $a \cdot b$ and $b \geq c$, then $b = b - 1$

if c · b and b ³ a, then $b = b - 1$;

if c £ $b - 2$, then $b = b - 1$.

- Repeat

4.1.2.3 Hybrid Median Filter:-

The hybrid median filter is another modification of median filter. This filter is also called as corner preserving median filter is a three-step ranking operation. In a 5X5 pixel neighboruhood, pixels can be ranked in two different groups. The median values of the 45° neighbours forming an " X" and the 90° neighbours forming a "+" are compared with the central pixel and the median value of that set is then saved as the new pixel value. The three step ranking operation does not impose a serious computational penalty as in the case of median filter. Each of the ranking operations is for a much smaller number of values than used in a square region of the same size. For example, the 5 pixel wide neighbourhood used in the examples contains either 25 (in the square neighbourhood) which must be ranked in the traditional method. In the hybrid method, each of the two groups contains only 9 pixels, and the final comparison involves only three values. Even with the additional logic and manipulation of values, the hybrid method is faster than the conventional median. This median filter overcomes the tendency of median and truncated median filters to erase lines which are narrower than the half width of the neighbourhood and to round corner[23].

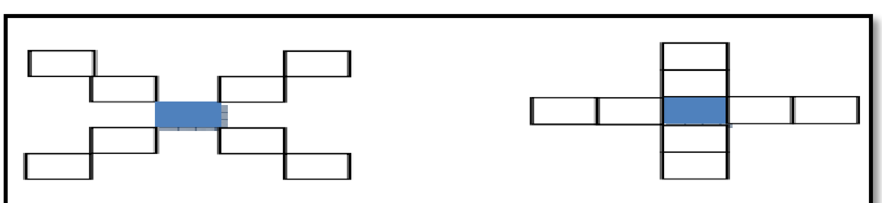


Figure.4.2: Diagram of neighborhood pixels used in the hybrid median filter [23].

4.1.3 Diffusion filtering:

Diffusion filters remove the noise from an image by modifying the image via solving a partial differential equation (PDE). Smoothing is carried out depending on the image edges and their directions. Anisotropic diffusion is an efficient nonlinear technique for simultaneously performing contrast enhancement and noise reduction. It smooth homogeneous image regions, but retains image edges [24, 25, 26].without requiring any information from the image power spectrum. It may, thus, directly be applied to images.
Consider applying the isotropic diffusion equation given by:-
d*gi*, *j*, *t* /d*t* = div(*d* Ñ*g*) using the original noisy image *gi*, *j*, *t* = 0 as the initial condition, where *gi*, *j*, *t* = 0 is an image in the continuous domain, *i* and *j* specify the spatial position, *t* is an artificial time parameter, *d* is the diffusion constant, and Ñ*g* is the image gradient.

4.1.3.1 Anisotropic Diffusion Filtering (DsFad):-Anisotropic diffusion filtering, proposed firstly by Perona and Malik in 1987 which is a nonlinear diffusion method used to avoiding the blurring and localization problems of linear diffusion filtering [27], and nonlinear technique for simultaneously performing contrast enhancement and noise reduction. It smoothes homogeneous image regions but retains image edges without requiring any information from the image power spectrum. Thus, it may be applied directly to logarithmic-compressed images. Modifying the image according to this linear isotropic diffusion equation is equivalent to filtering the image with a Gaussian filter. Diffusion is a physical process for balancing concentration changes. In image processing the image intensity can be seen as concentration. The noise can be modeled as little concentration in homogeneity. This in homogeneity could be smoothened by diffusion. Consider applying the isotropic diffusion equation given by

$d\, g_{i,□,\, t}/dt = \mathrm{div}\,(d\nabla g)$ using the original noisy image $g_{i,□,\, t=0}$ as the initial condition, where $g_{i,□,\, t=0}$ is an image in the continuous domain, i,j specifies spatial position, *t* is an artificial time parameter, d is the diffusion constant, and ∇g is the image gradient[8].

4.1.3.2 Speckle reducing anisotropic diffusion (SRAD):- Anisotropic Diffusion is a nonlinear smoothing filter which uses a variable conductance term that controls the contrast of the edges that influence the diffusion. This filter has the ability to preserve edges, while smoothing the rest of the image to reduce noise. The anisotropic diffusion has been used by several researchers in image restoration and image recovery.srad is an edge-sensitive Partial Differential Equation (PDE) anisotropic diffusion approach to reduce speckle noise in images. The anisotropic filtering in srad simplifies image features to improve image segmentation and smoothes the image in homogeneous area while preserving edges and enhances them. It reduces blocking artifacts by deleting small edges amplified by homomorphic filtering.

Srad equation for an image u is given by the Equation:-

$$(u') = ut+1 = ut + (\Delta t/4)\ \mathrm{div}\ (g\ (ICOV\ (u'))\ x\Delta\ u' \qquad (4.4)$$

Where :- t is the diffusion time index, ʃ´t is the time step responsible for the convergence rate of the diffusion process (Normally in the range 0.05 to 0.25), g(.) is the diffusion function and is given by equations (4.5) [28].

$$G(ICOV(u'))=e-(P) \qquad (4.5)$$

$$P = \frac{\left(\frac{ICOV(u')}{q^t}\right)^2 - 1}{1 + (q^t)^2} \qquad (4.6)$$

4.1.4 Wavelet filtering:

Wavelet filtering technique is a mathematical function based on the decomposition of the image data into the wavelet basis and zeroes out the wavelet coefficients (different frequency components) to despeckle the image and make use of a realistic distribution of the wavelet coefficients [29], where only the useful wavelet coefficients are utilized. Wavelet is much alike the traditional Fourier methods, but when the signal contains discontinuities and sharp spikes. Wavelet will have some advantages over traditional Fourier methods in handling the different type of noises which is present in an image [30]. Wavelet analysis is particularly useful for the analysis of transient, non stationary, or time varying signals, and can be used to analyze signals in different spatial resolutions. Their advantage is in their ability to analyze a signal with accuracy in both the time and frequency domains. And the wavelet techniques are widely used in the image processing, such as the image compression, image de-noising. It has been shown that its performance of image processing is better than the methods based on other linear transformation.

Wavelets based algorithm:

- ❖ 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, a hard threshold and soft threshold.

4.1.5 Total Variation Filter:

The total variation (TV) of a signal depend on that signals with excessive and possibly spurious detail have high total variation so the integral of the absolute gradient of the signal is high, which means that reducing the total variation of the signal subject to it will be close to the original signal, removes unwanted detail and preserve important details such as edges [31].

Because of its virtue of preserving sharp edges, it is widely used in many applications of image processing. Rudin et al. solved the total variation minimization problem through PDE-based schemes, which is numerical intensive. Besides, Chambolle's projection algorithm is a fast method to solve the Rudin-Osher-Fatemi (ROF) model given as,

$$u = f - P_{G_\lambda}(f) \quad (4.7)$$

Where f is the noisy image, u is the image we want to restore from f, $G_\lambda = \{v \in G / \|v\|_G \leq \lambda\}$, $P_{G_\lambda}(f)$ is the orthogonal projection of f on G_λ and the space G is proposed by Meyer for modeling oscillating patterns [30].

4.2 Image quality assessment: - quality is important when evaluating or segmenting ultrasound images, where speckle obscures subtle details in the image [32]. In a recent study [33] it is shown that speckle reduction improves the visual perception of the expert in the assessment of ultrasound imaging of the human organs. The statistical parameters like Signal to Noise Ratio (SNR), Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) for image quality assessment are described below. The following metrics are calculated using the original image X and the despeckled image Y. There are two major methods used to evaluate the image which are: the human organs. The statistical parameters like Signal to Noise Ratio (SNR), Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) for image quality assessment are described below. The following metrics are calculated using the original image X and the despeckled image Y. There are two major methods used to evaluate the image which are:

1. Human expert evaluation: This is hard to measure for not having particular parameters for the evaluation.

2. Image quality evaluation metrics: those are evaluation of an image use specific parameter to measure the difference between two images and they are easy to compute and have clear physical meaning.

Theses Image quality evaluation metrics are:

1. Mean squared error:

MSE is a statistical way to measures the quality change between the original image and denoised image (average of the squares of the errors) while the error is the amount by which the value implied by the original image differs from the denoised image. The difference occurs because of randomness or because the estimator doesn't account for information that could produce a more accurate estimate [18].

- Smaller MSE indicate that the estimate is closer to original image.
- The root MSE (RMSE), which is the square root of the squared error averaged over an M X N window:

$$\text{RMSE} = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(g_{i,j} - f_{i,j})^2}. \quad (4.7)$$

The popularity of the RMSE arises mostly from the fact that it is, in general, the best approximation of the standard error.

2. Signal-to-noise ratio:

Signal-to-noise ratio (SNR) is a measure used to compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels (dB). A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise [18].

- The higher the ratio, the less obtrusive the background noise is. SNR is calculated as follows:-

$$\text{SNR} = 10\log_{10}\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(g_{i,j}^2 - f_{i,j}^2)}{\sum_{i=1}^{M}\sum_{j=1}^{N}(g_{i,j} - f_{i,j})^2} \quad (4.8)$$

3. Peak signal-to-noise ratio:-

Peak signal-to-noise ratio (PSNR), is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects it. It measures image fidelity, that is, how closely the transformed image resembles the original image [18].

❖ The PSNR is higher for a better transformed image

PSNR can be defined as: $$\mathrm{PSNR} = -10\log_{10}\frac{\mathrm{MSE}}{g^2_{\max}}$$ (4.9)

4. Structural similarity index method:-

The structural similarity (SSIM) index is a method for measuring the similarity between two images. The SSIM index is a full reference metric; in other words, the measuring of image quality based on an initial uncompressed or distortion-free image as reference. SSIM is designed to improve on traditional methods like peak signal-to-noise ratio (PSNR) and mean squared error (MSE), which have proven to be inconsistent with human eye perception.

The difference with respect to other techniques mentioned previously such as MSE or PSNR is that these approaches estimate perceived errors; on the other hand, SSIM considers image degradation as perceived change in structural information. Structural information is the idea that the pixels have strong inter-dependencies especially when they are spatially close. These dependencies carry important information about the structure of the objects in the visual scene [18].

SSIM index results in decimal value between -1 and 1 where 1 indicate two identical sets of data.

$$\mathrm{SSIN} = \frac{(2\bar{g}\bar{f} + c_1)(2\sigma_{gf} + c_2)}{(\bar{g}^2 + \bar{f}^2 + c_1)(\sigma_g^2 + \sigma_f^2 + c_2)}, -1 < \mathrm{SSIN} < 1,$$ (4.10)

4.3 Methodology:-

Generally, the denoising filters can destroy some of the relevant image details that are of interest for the physicians; so in medical imaging it's necessary to choose a noise reduction filter that can preserve the features and fine details of the image.

A group of filters explained in previous which are DsFca, DsFgf4d, DsFsrad, DsFmedian, DsFwiener, Tvdenoise and DsFwaveltc were chosen so as to specify which one is better in speckle noise enhancement. **For the performance evaluation of these filters,** and how they affect the image quality; the two different type of ultrasound images were used (liver and kidney us images) is obtained from public image database Medison available at http://www.medison.ru/uzi. and a speckle noise is added to each image with values of (50%) and (5%) and the four different quality measures were applied between the original liver and kidney image (before applying the speckle noise) and after applying each of the filters specified before. evaluation is made via Image quality evaluation metrics. All preprocessing and validation procedures are implemented using MATLAB R2008a.

4.4 Result and discussion:-

4.4.1: results of despeckle filter:.

Original image

noisy image

hybrid median

Srad

wavelet

DsFca

TV denoise

DsFgf4d

Figure4:3. Results of applying despeckle filter on ultrasound image (liver) with multiplication noise (σn=0.05).

Table 4.1: Image quality evaluation metrics for the liver image with additive (0.05) Speckle noise.

Filter type	Image quality evaluation metrics			
	RMSE	SNR	PSNR	SSIM
Hybrid median filter	0.0287	9.7071	78.9769	0.8344
Linear scaling filter	0.0506	7.3673	74.0433	0.6076
Wavelet filter	0.0280	9.8623	79.1949	0.8104
Total variation filter	0.0284	9.7605	**79.0575**	0.7702
Geometric filter	0.1027	5.0930	67.9621	0.5797
DsFsrad	0.0320	9.2438	77.9960	0.7921

RMSE root mean square error; SNR, signal-to-noise ratio; PSNR peak signal-to-noise ratio; SSIM structural similarity index method

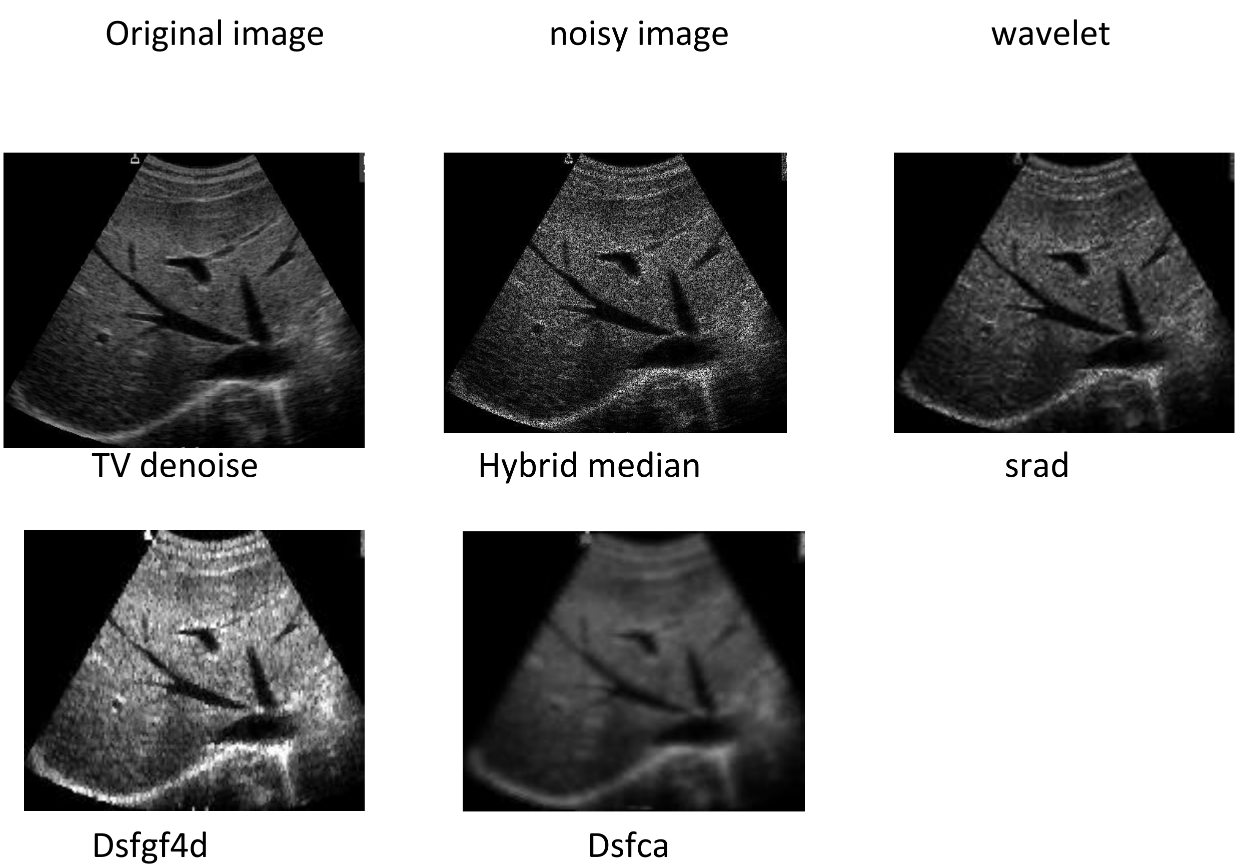


Figure4:4. Results of applying despeckle filter on ultrasound image (liver) with multiplication noise (σn=0.5).

Table 4.2: Image quality evaluation metrics for the liver image with additive (0.5) Speckle noise.

Filter type	Image quality evaluation metrics			
	RMSE	**SNR**	**PSNR**	**SSIM**
Hybrid median filter	0.0738	5.7132	70.7688	0.5760
Linear scaling filter	0.0646	6.5921	71.9259	0.5929
Wavelet filter	**0.0508**	**7.3440**	**74.0177**	0.7012
Total variation filter	0.0580	6.7894	**72.8615**	0.6853
Geometric filter	0.2108	3.0899	61.6569	0.4623
DsFsrad	0.0641	6.6174	71.9953	0.7191

RMSE root mean square error; SNR, signal-to-noise ratio; PSNR peak signal-to-noise ratio; SSIM structural similarity index method



Original image NOISY image hybrid median

Srad dsfgf4d TV denoise

Wavelet DsFca

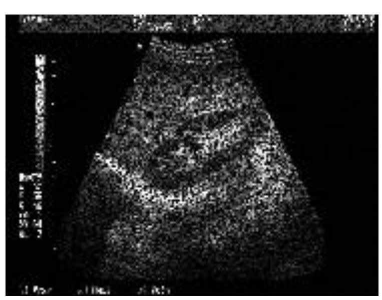
Figure 4.5: Results of applying despeckle filter on ultrasound image (kidney) with multiplication noise (σn=0.05).

Table 4.3: Image quality evaluation metrics for the kidney image with additive (0.05) Speckle noise

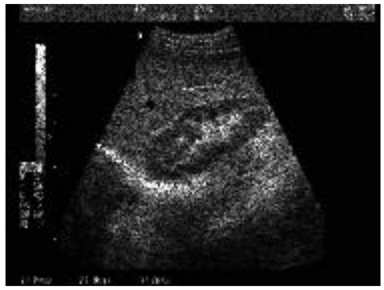
	Image quality evaluation metrics

Filter type	RMSE	SNR	PSNR	SSIM
Hybrid median filter	0.0820	5.4936	69.8573	0.6331
Linear scaling filter	0.0618	6.8680	72.3125	0.5663
Wavelet filter	**0.0402**	**8.6179**	**76.0557**	0.7444
Total variation filter	0.0396	8.6405	**76.1736**	0.8379
Geometric filter	0.1200	4.8213	66.5493	**0.5391**
Dsfsrad	0.0424	8.3429	75.5856	0.7139

RMSE root mean square error; SNR, signal-to-noise ratio; PSNR peak signal-to-noise ratio; SSIM structural similarity index method



Original image Noisy image dsfca



Wavelet hybrid median

Srad DsF4gf

figure4.6: Result s of applying despeckle filter on ultrasound image (kidney) with multiplication noise (σn=0.5).

Table 4.4: Image quality evaluation metrics for the kidney image with additive (0.5) Speckle noise.

Filter type	Image quality evaluation metrics			
	RMSE	SNR	PSNR	SSIM

Hybrid median filter	0.1075	4.3837	67.5016	0,5630
Linear scaling filter	0.0803	5.8869	70.0410	0.5663
Wavelet filter	**0.0694**	**6.2932**	**71.3012**	0.7444
Total variation filter	0.0719	6.2079	**71.0947**	0.8379
Geometric filter	0.2179	3.1498	61.3674	0.5391
Dsfsrad	0.0670	6.2316	71.6103	0.6340

R MSE root mean square error; SNR, signal-to-noise ratio;PSNR peak signal-to-noise ratio;SSIM structural similarity index method.

4.4.2 Discussions:-

As explained above we shall compare all filters that explain previous and this based on four image quality evaluation metrics along with the Structural similarity index method are the methods that used to evaluate the results of the denoising filters and the results were as follow: Figures

4.1 to 4.4and the tables 4.1 to 4.4 are displaying the image quality evaluation metrics of the different known filters applied on two different ultrasound images , Most filters are not bad ,so the value of quality matrices of wavelet and tvdenoise filter which have higher snr and psnr that mean the image is good and in tvdenoise
Reduces the loss of destroying details, but the noise-eliminated capability is weak.

CHAPTER FIVE
HYBRID TECHNIQUE

This chapter explained the proposed technique that used to denoised us image, this technique is a combination of wavelet decomposition and reconstructed by TV denoise filter.

5.1 Wavelet transforms One of the most useful denoising tool for the image is the wavelet transforms which have been proven to be the right tool for one-dimensional piecewise smooth signals, like scan lines of an image, because they provide an optimal representation for these signals [34], and in two-dimensional signals it consider good at isolating the discontinuities at edge points and can capture only limited directional information which is an important and unique feature of multidimensional signals but in the other hand will not see the smoothness along the contours. Wavelet-based denoising algorithm has been studied and applied successfully for speckle removal. Compact and in the recent year there have been significant investigations in medical imaging area using the wavelet transform as a tool for improving medical images from noisy data. Wavelet denoising attempts to remove the noise present in the signal while preserving the signal characteristics, regardless of its frequency content. As the discrete wavelet transform (DWT) corresponds to basis decomposition, it provides a non redundant and unique representation of the signal [35]. In wavelet transform based decomposition, the original image is divided into low-frequency information and high-frequency information. If we apply a wavelet decomposition, the correspond sub bands will represent either low pass filtering or high pass filtering in each direction. The procedure for wavelet decomposition consists of consecutive operations on rows and columns of the two-dimensional data. In two-dimensional discrete wavelet analysis, the wavelet transform first performs one step of the transform on all rows. This process yields a matrix where the left side contains down sampled low pass coefficients of each row, and the right side contains the high pass coefficients [36]. The operation decomposes the image into four sub bands (LL, HL, LH and HH) as shown in.

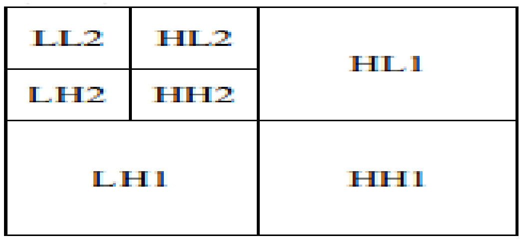


figure 5.1: Two-Level image decomposition by using DWT [36]

The HH subband gives the diagonal information of the US image; the HL subband gives the horizontal features while the LH subband represents the vertical structures of the US image. The LL subband is the low-resolution residual consisting of low frequency components and this subband is further divided at the higher levels of decomposition. The different methods of wavelet denoising investigated so far differ only in the selection of the threshold [37].All the wavelet filters use wavelet thresholding operation for denoising. Speckle noise is a high-frequency component of the image and appears in wavelet coefficients.

5.2 Proposed method:

As resolve of the weakness of filters explained in chapter four a hybrid technique that combined the two filters together can denoise the speckle noise and preserve the texture too. The hybrid method proposed in this is to get use of the advantage of the wavelet method and the TV based method. The noisy image is decomposed into four sub bands using the wavelet decomposition up to one level of decomposition which results in LL, HL, LH and HH sub bands.

- TV denoising method is applied to the LL sub band which contains the low frequency coefficients and less noise, so the noise can be easily remove without affecting the image fine details.
- In order to extract edges and textures from the high frequency coefficients in the other three sub bands, a wavelet filter is applied with a proper thresholding value that will reduce the noise with great value and extract useful feature form the high frequency sub band that contain more noise.
- finally the image reconstruction is made through the IDWT to obtain the dnoised image

5.2.1 Filter algorithm:

Step one: input the original image.

Step two: Add speckle noise to the original image

Step three: apply wavelet decomposition to the noisy image, to decompose the noisy image to third level's sub bands and get LL1 from first level decomposition and LH3, HL3, HH3 from the third

Step four: apply TV filter in LL subband.

Step five: apply wavelet filter in HL, LH and HH sub bands.

Step six: apply wavelet reconstruction to the image.

Flow chart:-

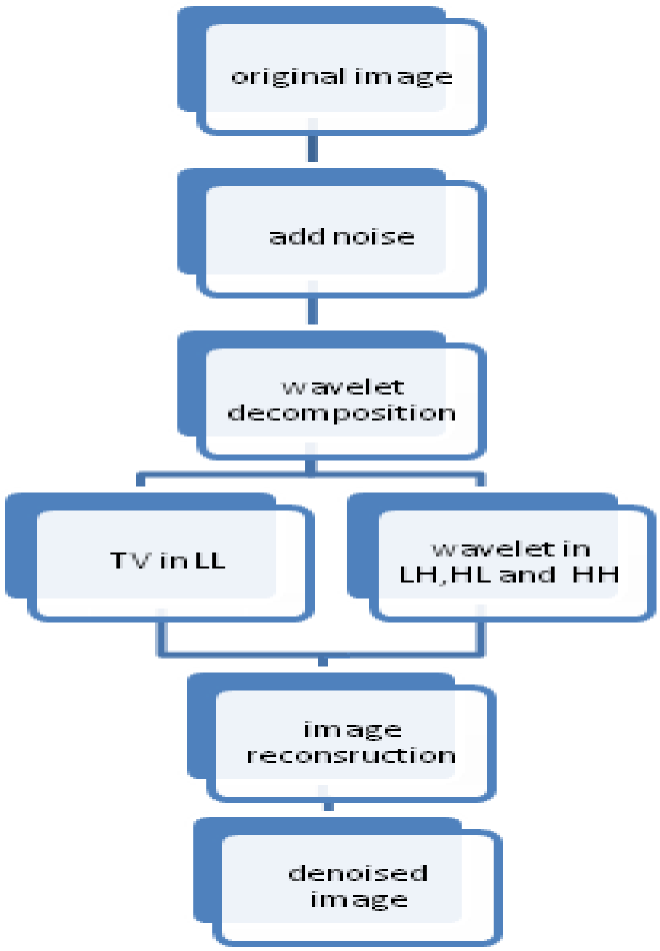
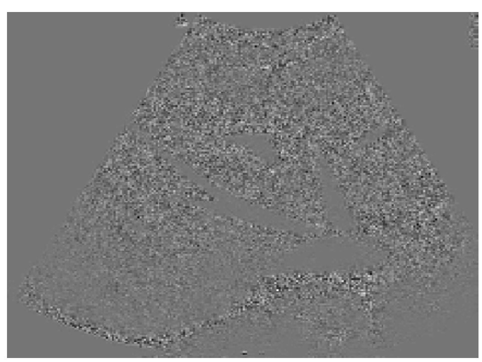


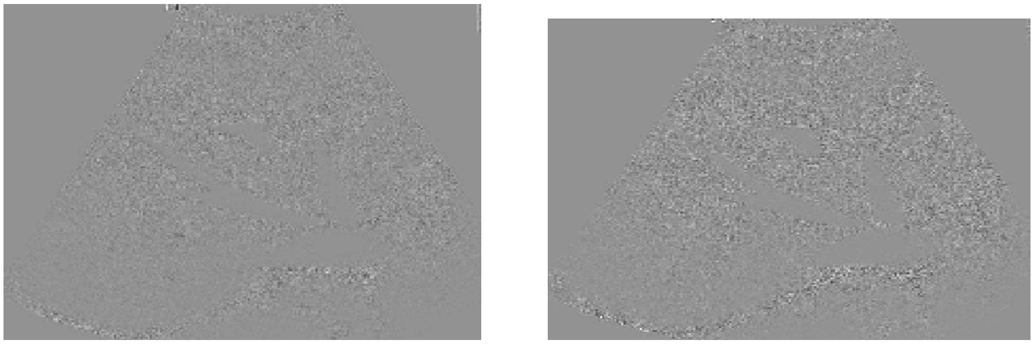
Figure 5.2: Work flow. The input image was noise free image and the speckle noise added to it then denoised by different types of filters and evaluated

5.2.2 Experimental results and evaluation*:-* In this chapter the proposed method has been implemented in the MATLAB 2008a,and it is applied on two different ultrasound images, and then the speckle noise added to it with values of value σ = 0.05 and 0.5 using the MATLAB command "imnoise (image, 'speckle', 0.05 or 0.5). And the resulting images has been evaluated by the speckle reduction method various measures may be used. The commonly preferred measures are mean squared error (MSE), signal to noise ratio (SNR), peak signal to noise ratio (PSNR) and structural similarity index (SSIM), which have been calculated from the denoised US images and are found in the literatures. The PSNR and SNR is higher for a better-transformed image and lower for a poorly transformed image. Whilst the range of values for the SSIM lies between −1, for bad and 1 for good similarity between the original and despeckled images. And also the differences between the original, and the despeckled images were evaluated using image quality evaluation metrics. The following measures, which are easy to compute and have clear physical meaning. Figure 5.3 below show sub bands for the wavelet decomposition of the image that show clearly that most of the image texture is suppressed on the LL sub band and the high frequency noise is on the other three sub bands (HL, LH and HH). As the proposed method imply the TV filter is applied on the LL sub band since it's consider as a good filter for noise reduction, and a wavelet filter is applied on the three other sub bands (HL, LH and HH). To act as an edge detector. The inverse wavelet transform is applied on to four sub bands to reconstruct the denoised image.

CA1≡ **approximation detail**



cH1≡**horizental detail**



CV1≡ **vertical** detail CD1≡**diagonal detail**

Figure 5.3: The wavelet decomposition of the liver image (noise.05)

Original image noisy image proposed method

figure5.4:-The results after applying the hybrid technique on a liver image with additive of (0.05) speckle noise

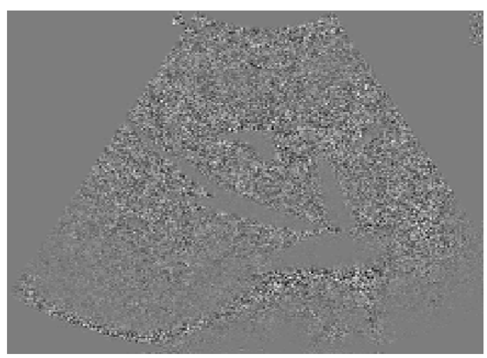
Table5.1: Image quality evaluation matrices of the transvaginal ultrasound image (liver) with speckle noise (0.05):

Filter type	**Image quality evaluation metrics**			
	RMSE	**SNR**	**PSNR**	**SSIM**
Hybrid median filter	0.0287	9.7071	78.9769	0.8344

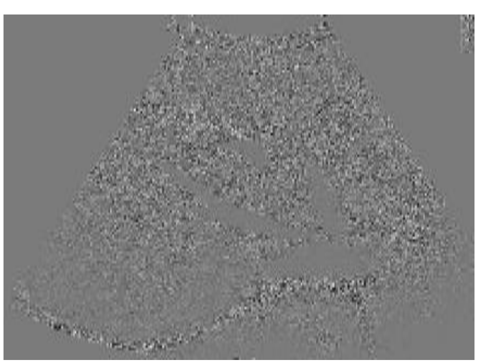
Linear scaling filter	0.0506	7.3673	74.0433	0.6076
Wavelet filter	0.0280	9.8623	79.1949	0.8104
Total variation filter	0.0284	9.7605	**79.0575**	0.7702
Geometric filter	0.1027	5.0930	67.9621	0.5797
Dsfsrad	0.0320	9.2438	77.9960	0.7921
Proposed method	**0.0278**	**9.8747**	**79.8747**	**0.8535**

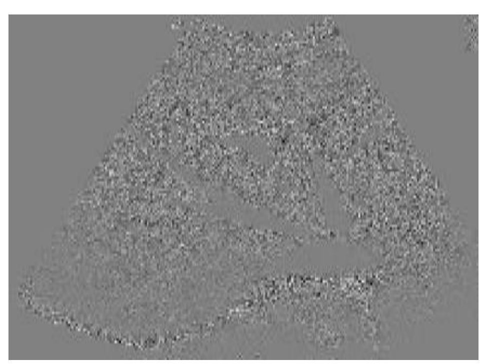
RMSE root mean square error; SNR, signal-to-noise ratio; PSNR peak signal-to-noise ratio; SSIM structural similarity index method.

cA1≡ **approximation detail**



cH1≡**horizental detail**





CV1≡**vertical detail** cD1≡**diagonal detail**

Figure 5.5: The wavelet decomposition of the liver image(noise.5)

Original image noisy image proposed method

Figure 5.6: The results after applying the hybrid technique on a liver image with additive of (0.5) speckle noise

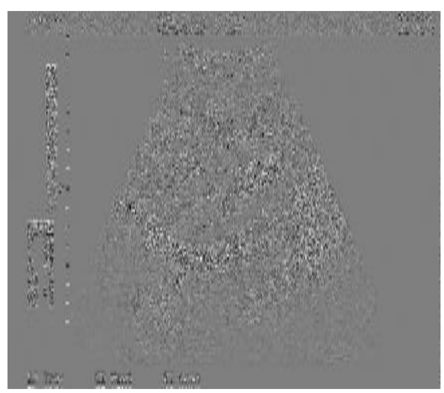
Table 5.2: Image quality evaluation matrices of the liver image with additive of (0.5) of speckle noise

Filter type	**Image quality evaluation metrics**			
	RMSE	**SNR**	**PSNR**	**SSIM**
Hybrid median filter	0.0738	5.7132	70.7688	0.5760
Linear scaling filter	0.0646	6.5921	71.9259	0.5929

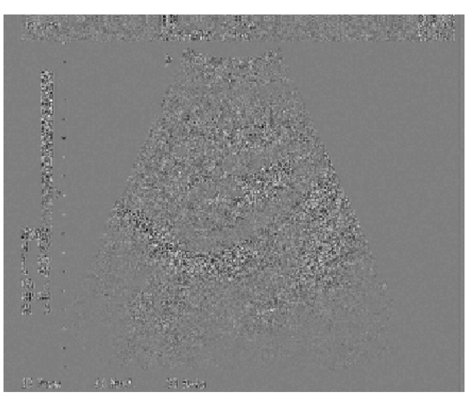
Wavelet filter	**0.0508**	**7.3440**	**74.0177**	0.7012
Total variation filter	0.0580	6.7894	**72.8615**	0.6853
Geometric filter	0.2108	3.0899	61.6569	**0**.4623
Dsfsrad	0.0641	6.6174	71.9953	0.7191
Proposed method	**0.0499**	**7.3791**	**74.1642**	**0.8156**

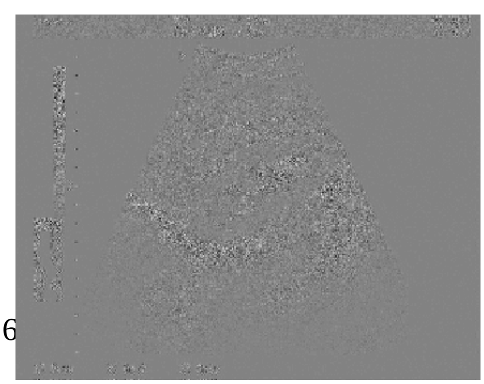
RMSEroot mean square error; SNR, signal-to-noise ratio; PSNR peak signal-to-noise ratio;SSIM structural similarity index method.

A1=Approximation detail



cH1≡**horizental detail**





CV1≡**vertical detail** cD1≡**diagonal detail**

Figure 5.7: The wavelet decomposition of the kidney image (noise.05)

Original image noisy image propsed method

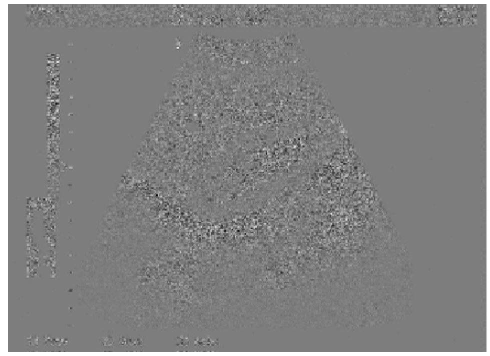
Figure 5.8: The results after applying the hybrid technique on kidney image with speckle noise (.05).

Table 5.3: Image quality evaluation matrices of the kidney image with additive of (0.05) of speckle noise

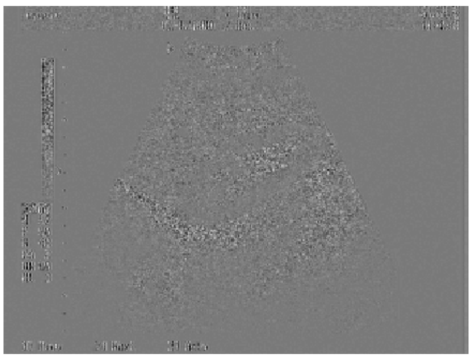
Filter type	Image quality evaluation metrics			
	RMSE	**SNR**	**PSNR**	**SSIM**
Hybrid median filter	0.0820	5.4936	69.8573	0.5630
Linear scaling filter	0.0618	6.8680	72.3125	0.5663
Wavelet filter	**0.0402**	**8.6179**	**76.0557**	0.7444
Total variation filter	0.0396	8.6405	**76.1736**	0.8379
Geometric filter	0.1200	4.8213	66.5493	0.5391
Dsfsrad	0.0424	8.3429	75.5856	0.6340
Proposed method	**0.0.0389**	**8.7330**	**76.3395**	**0.8453**

RMSE root mean square error; SNR, signal-to-noise ratio;PSNR peak signal-to-noise ratio;SSIM structural similarity index method.

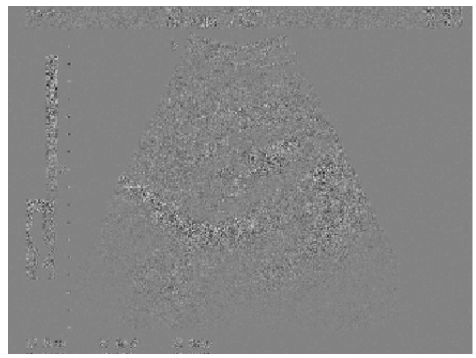
A1=Approximation detail



cH1≡**horizental detail**



CV1≡**vertical detail**



cD1≡**diagonal detail**

Figure 5.9: The wavelet decomposition of the kidney image (speckle noise.5)

Original image

noisy image

proposed method

Figure5.10 the results after applying the hybrid technique on kidney image with additive of (0.5) speckle noise

Table 5.4: Image quality evaluation matrices of the liver image with additive of (0.5) of speckle noise

Filter type	Image quality evaluation metrics			
	RMSE	**SNR**	**PSNR**	**SSIM**
Hybrid median filter	0.1075	4.3837	67.5016	0.5034
Linear scaling filter	0.0803	5.8869	70.0410	0.5663
Wavelet filter	**0.0694**	**6.2932**	**71.3012**	0.7444
Total variation filter	0.0719	6.2079	**71.0947**	0.8379
Geometric filter	0.2179	3.1498	61.3674	0.5391
Dsfsrad	0.0670	6.2316	71.6103	0.6360
Proposed method	**0.0640**	**6.6059**	**72.0277**	**0.8735**

RMSE root mean square error; SNR, signal-to-noise ratio; PSNR peak signal-to-noise ratio; SSIM structural similarity index method.

5.3 discussions:-

This chapter present the denoising method that proposed in this thesis as a speckle noise reduction filter in details and the evaluation of the proposed method by means of (MSR, SNR, PSNR and SSIM) and Each parameter measures a specific means of these filters, as explained in chapter four a smaller MSE indicates that the denoised image is closer to the original image, and when the SNR and PSNR is higher, the transformed image is better and when its lower, indicate to poorly transformed image. The results were as follow:

Tables (5.1) to (5.4) were displaying the image quality evaluation metrics of the filters and the figures from (5.3) to figure (5.10) shown the resultant image of the proposed filter. The final conclusions extract from the quality evaluation metrics proposed that the hybrid technique can produce better denoised image and preserves edges better as the tables of the image quality evaluation metrics output of the hybrid technique indicate.

CHAPTER SEX

CONCLUSION AND FUTURE WORK

6.1 Conclusion:-

US is relatively inexpensive, portable, safe, and real time in nature. These characteristics, and continued improvements in image quality and resolution have expanded the use of US to many areas in medicine beyond traditional diagnostic imaging applications.

In this research, a study and comparative of ultrasound image filtering techniques for speckle noise reduction is made using different types of spatial and transform filters (geometric, hybrid median, linear scaling, speckle reduction anisotropic diffusion, Total variation, wiener filter, and wavelet filter).These filters were simulated on MATLAB, applied to different types of ultrasound images and for estimate purpose using the statistical parameters for the analyze.

A new and effective method based on the wavelet domain decomposition companied with the total variation filter for US image enhancement has been proposed in this research. The implemented investigation and obtained results by using real images attempt to make diagnostic more obvious. This method simulated on MATLAB, applied in two different ultrasound images and then evaluated with statistical parameters, and finally a comparison between the spatial and the new filter is made. Previously was made, different noise levels were used to demonstrate that the proposed method is capable to reduce noise and preserve image texture better than the other filtering techniques. The hybrid technique yield better results as it reduce noise, preserved texture and fine details of the image that can

Enhance the diagnosis ability of the image by the physicians and experts.

6.2 Recommendation:-

In the field of image denoising, more researches are needed to develop very effective filters as the wavelet transform is affected by the thresholding level and an evaluation of the new technique is required to evaluate the impact of the new filter in clinical practice. And try to use another type from wavelet transformer family such as: db8,

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