

**T.C.
ISTANBUL AYDIN UNIVERSITY
INSTITUTE OF SCIENCE AND TECHNOLOGY**



WAVELET BASED IMAGE FUSION IN BIOMEDICAL

THESIS

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**Department of Electrical & Electronic Engineering
Electrical and Electronics Engineering Program**

May, 2019

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T.C.
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Not: Öğrencinin Tez savunmasında **Başarılı** olması halinde bu form **imzalanacaktır**. Aksi halde geçersizdir.

I extend my deepest gratitude to family, whose has been a constant source of support and encouragement during all the challenges in my life.

DECLARATION

I hereby declare that all information in this thesis document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results, which are not original to this thesis.

Molham MOSHANTAT

FOREWORD

I would first like to thank my thesis advisor Assoc.Prof. Dr. Saeid KARAMZADEH of the Electric and Electronic Engineering at Istanbul Aydin University. The door to Prof. KARAMZADEH office was always open whenever I ran into a trouble spot or had a question. He consistently allowed this paper to be my own work but steered me in the right the direction whenever he thought I needed it. I would like also to thank Istanbul Aydin University and its library for providing me with an access to all the books and articles that I needed to finish this work.

May 2019

Molham Moshantat

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ABBREVIATIONS

ANN	: Artificial Neural Networks
Bior	: Biorthogonal wavelets
BT	: Brovey Transform
CAD	: Computer Aided Diagnosis
CT	: Computed Tomography
CWT	: Continuous Wavelet Transform
DSA	: Digital subtraction angiography
DWT	: Discrete Wavelet Transform
DICOM	: Digital Imaging and Communication in Medicine
Db	: Daubechies Wavelets
HPF	: High Pass Filtering
HIS	: Intensity-Hue-Saturation
IDWT	: Inverse Discrete Wavelet Transform
MRA	: Multi resolution Analysis Based Method
MRI	: Magnetic Resonance Imaging
NEMA	: National Electrical Manufacturers Association
NMR	: Nuclear Magnetic Resonance
NSCT	: Non-Sub-Par Contourlet change
PCA	: Principle Component Analysis
PCNN	: Pulse Coupled Neural Network
PET	: Positron Emission Tomography
PSNR	: Peak Signal to Noise Ratio
SD	: Standard Deviation
SYM	: Symlets Wavelets
SPECT	: Single-photon emission computed tomography

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BIYOMEDİKALDE DALGACIK ESASLI GÖRÜNTÜ FÜZYONU

ÖZET

Bu günlerde, tıbbi görüntülemeyi hastanelerde kullanmamız çok önemli. Tıbbi görüntüleme bize insan vücudu hakkında detaylı ve önemli veri ibraz etmekte. Manyetik rezonans görüntüleme bize doku verileri ibraz eder. Pozitron yayınlıyıcı tomografi ve tek foton tomografi bize tüm vücudun işlevselliğini ibraz etmektedir. Fakat hastalık tanı ve tedavi planlaması için bu görüntülemeleri bize çok net verileri veremez. Bu nedenle, etkili hastalık analizi için bu farklı modeliste tamamlayıcı veriler gereklidir. Bu veri multimodality medikal görüntü füzyon algoritmaları ile geçirmekte. Bu noktada, kapsamlı araştırmalarında tıbbi görüntüler için birçok füzyon algoritması üzerinde çalışmaktadır. Tıbbi görüntü füzyonu ise, en az iki tıbbi görüntüyü bir görüntüde birleştiren yöntemdir, kaydedilen tıbbi görüntülerin her ikisinin de verilerini içermekte. Bu teknik temel olarak taşıstan parçası olarak kullanılır. Görüntü füzyonunun ana amacı, iki görüntünün verilerini veya tek bir görüntünün her birinden istenen özellikleri birleştirmektir.

Bu tezde wavelet'I (kesikli dalgacık dönüşümü) kullanarak iki tıbbi görüntülemeleri birleştirmek için bir program tasarladık. Sonra bu görüntüdeki tüm dalgacık türlerine uygulandığında en iyi sonucu tartıştık ve dalgacık kullanan tıbbi görüntü üzerinde görüntü füzyon tekniğini kullandık db,coif,sym,dmey,bior,rbio, ve haar. Bu füzyon algoritmaları farklı performans parametreleri kullanılarak analiz edilmektedir örnek olarak "Entropy, PSNR, SD, SNR" en iyi metodu seçebilmesi için.

Anahtar Kelimeler: *Görüntü füzyonu, DWT, PSNR, IDWT, CT, MRI, Entropi, Füzyon kuralları.*

WAVELET BASED IMAGE FUSION IN BIOMEDICAL

ABSTRACT

In these days, using medical image is very important in hospitals. These medical images give a lot of data about human body for example Computed Tomography (CT) identifies the bone structure, Magnetic Resonance Image (MRI) image gives that the so tissue data, Positron on Emission Tomography (PET) and Single photon release computed tomography (SPECT) give human body functionality data. but these images can't give clear data image for disease diagnosis and treatment planning. So, these different modality complementary data for effective disease analysis is required. This data is gone through the multimodality medical image fusion Algorithms. To this point, comprehensive research has been conducting on a lot of fusion algorithms for medical images. Whereas Medical image fusion is the method which merge at least two medical images into one image, which contains the data of both the recorded medical image. This technique is fundamentally utilized as a part of diagnosis. The main goal of Image fusion is to combine data from two images or more the required features from each of the single image. Typically, images like MRI and CT are utilized as source image. Discrete Wavelet Transform is utilized for the medicinal image combination execution.

In this thesis we designed a program to merge two medical image (MRI and CT) using wavelet transform (Discrete Wavelet Transform) and discussed the best result when applied to all types of wavelets on this image and we used image fusion technique are performed on medical image utilizing wavelets like db, coif, sym, dmey, bior, rbio and haar. These fusion Algorithms are analyzed using different performance parameters like Entropy, PSNR, SD, SNR to choose the better methods.

Keywords: *Image fusion, DWT, PSNR, IDWT, CT, MRI, Entropy, Fusion rules.*

1. INTRODUCTION

These days, with the accelerate advancement in high-technology and contemporary instrumentation, medical imaging is now an essential part of a high number of applications, such as diagnosis, research, and treatment, for medical examination, just one sort of image might not be enough to supply accurate clinical prerequisite for your doctors. Consequently, the combination of this multi-modal medical images is required (Hari Om Shanker Mishra and Smriti Bhatnagar, (2014)). Medical imaging provides many modes of images information for the clinical examination including. Different medical images have different features, which may provide structural knowledge of distinct organs. By way of instance, CT (Computed tomography) and MRI (Magnetic resonance image) with high spatial resolution might offer anatomical construction info of organs. Thus, Large collection of imaging to get the exact same organ, they're contradictory but interrelated and complementary. As a result, the right image fusion of distinct features becomes an urgent necessity for clinical examination (A. Soma Sekhar, Dr.M.N.Giri Prasad, (2011)). In this thesis, we will design a program to merge MRI and CT image using a discrete wavelet transform in each kind of wavelet than discuss which is the best wavelet give us the best result, and in this chapter, we are going to briefly explain about computed tomography (CT) and magnetic resonance imaging (MRI).

1.1 Computed Tomography

One of the tomographic modalities, CT is most frequently than the MRI because every modality yield images of the body in broadly similar levels of detail using diverse shades of grey, and both supply images from any place within the body. On the other hand, the fundamentals of how images are formed and also the look of particular cells in each modality are extremely different. Much like MRI and the rest of the imaging procedures, CT creates the image by sending energy (x-ray) to your system and measuring the way that energy is consumed or

altered if passing through the human body's cells. Detectors quantify how much energy moves through the body around the other hand

which then informs how far the beam was attenuated, which is, how much energy has been consumed by the cells. The x-ray ray is put at many distinct angles, and the subsequent dimensions are processed by a computer to generate a cross-sectional image. Both the displayed brightness of this tissue at each stage along with the comparison between different cells from the image reveals just how much x energy is consumed. By way of instance, bone is among the denser cells within the body, therefore it consumes more x-rays and consequently appears glowing on a CT image. Blood, cerebrospinal fluid (CSF), plus a few soft cells are of lesser density so consume less of this x-ray, causing a darker, for example, the axial image of the brain that shown in Figure 1.1 (Url-1).

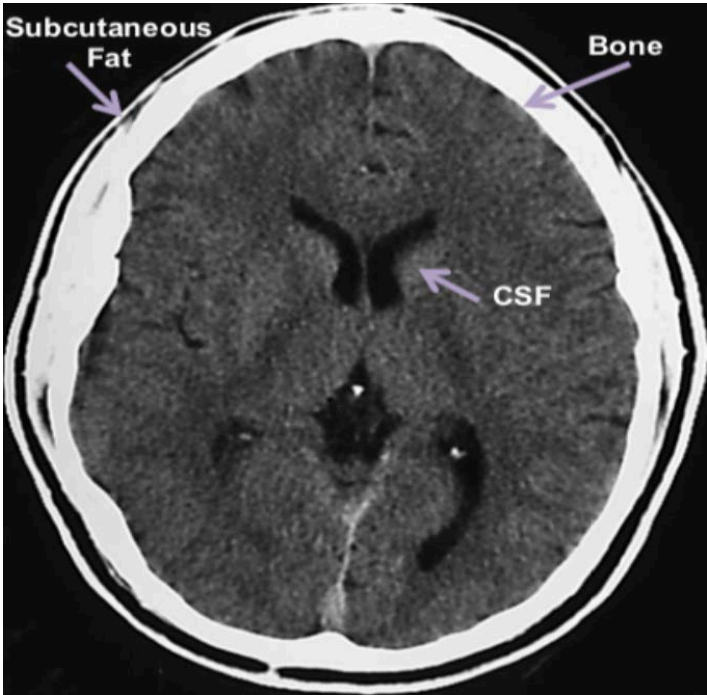


Figure 1.1: Axial image of brain.

Source: Url-2

The three-dimensional images taken to the internal body structures using CT are based on X-ray imaging and are performed using a computer, and that images of x ray are obtained by exposing the patient to some fan-shaped x-ray column and then discovering the projected image onto a thin semicircular, digital x-ray sensor. Each picture is an x ray projection of a somewhat thin transverse portion

of the human body. To collect the large number of x ray projections necessary to generate a tomographic CT picture, both the x ray source and detector are rotated around a patient within a reassuring gantry(A. Soma Sekhar, Dr.M.N.Giri Prasad, (2011), Figure 1.2 shown us the external structure of the CT.



Figure 1.2 : External structure of the CT.

Source: Url-1

To enhance image-capture occasions and resolution, manufacturers use multi-slice CT imaging methods. Rather than a single 2 dimensions detector provide just a single image slice, multi-slice imaging employs 3 dimensions collection. The extra imaging measurement permits the system to create numerous pieces in parallel. About 1000 detectors are used in optical detector matrices in the extended measurement along the semicircular sensor arc; sixteen or even more detectors sit from the squab by measurement tangent into the arc, Figure 1.3 shown us that. The number of sensors from the short size determines the amount of available picture bits (Url-4).

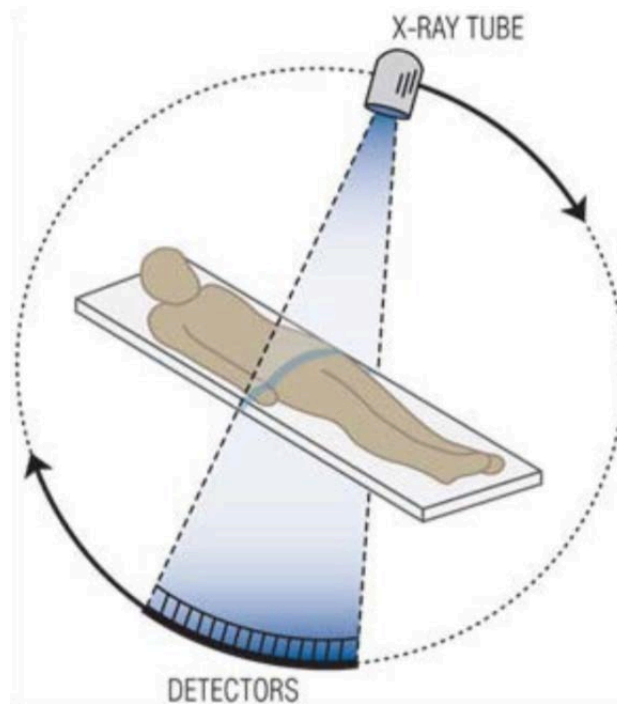


Figure 1.3: person was exposed to some X-ray beam in the form of a fan and the projected image can also be shot to the semi-circular digital X Ray sensor

Source: Url-1

CT imaging methods may create images in the entire body using a method known as spiral CT. At a spiral-CT system that the patient is gradually moved to the middle of this gantry whereas the x-ray source and detectors rotate around the patient (Url-1).

1.2 Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a medical imaging technique Which capture magnetic fields as well as magnetic resonance imaging and the impact and unique images on which the pulse sequence capable of whole human body scans, but generally employed for a brain (Hongmei Zhu, (2011).). Magnetic resonance imaging (MRI) has become among the most effective and flexible diagnostic instruments available to clinicians and investigators now. There's been enormous growth in both clinical and technology use as MRI first became commercially available. The resolution, image quality, and period required for MRI examinations have enhanced considerably with the design of strong high-field magnet layouts, high-performance gradient systems, a broad selection of technical radiofrequency coils, and improvement of computer engineering.

These new capacities have yielded exquisitely detailed graphics in every area of the human body, bringing innovative technologies like functional brain imaging, whole-body diffusion imaging, fiber monitoring, and real-time neural imaging from the research laboratory and into clinical practice. Improvements in software and hardware technology also have allowed the development of consumer-friendly, advanced processing, and viewing tools to further improve the diagnostic skill of clinicians. Because of This, MRI has become routinely used to get an ever-expanding assortment of diagnostic assessments, providing better advice to clinicians, reducing danger to patients by eliminating the need for invasive and radiation processes and generating enhanced identification and therapy programs (Prince. Jerry, 2006).

1.3 Development of magnetic resonance imaging

MRI is determined by the physical principles of nuclear magnetic resonance (NMR). In 1945 in separate experiments, felix bloch in stanford university and edward purcell at harvard university found that delivering particular radio waves to substances exposed to a strong magnetic field led to the substance to absorb the power of the waves that could subsequently be discovered since the power radiated back. Further experiments discovered that the precise group of consumed frequencies supplied advice regarding the arrangement of the atomic nucleus and its chemical environment. By analyzing the spectrum of consumed frequencies, the arrangement of complex molecules can be set. This evaluation technique is called nuclear magnetic resonance (NMR) spectroscopy or magnetic resonance spectroscopy (MRS) and is still a principal means for identifying the structure of proteins and several different molecules. Back in 1952, Bloch and Purcell have been given the Nobel Prize in physics for their pioneering work in nuclear magnetic resonance experimentation (Prince. Jerry, 2006).

1.4 Magnetic resonance imaging components

MRI scanner is shown in figure 1.4 includes three major hardware elements: a major magnet, a magnetic field gradient system, and a radio-frequency (RF) system. The most important part is a permanent magnet. It creates a solid

uniform static area, known as the B0 area, for polarization of nuclear spins within an item. The magnetic field gradient system generally includes 3 Orthogonal gradient coils, Gx, Gy and also Gz, essential for signal localization. The gradient field advantage is usually significantly less than 1 G/cm. The RF system is made up of transmitter coil that's capable of creating a rotating magnetic field, known as the B1 area, for arousing a twist method, and a receiver coil which converts a processing magnetization to an electric signal. On human imaging methods, the potency of B1 is generally a tiny portion of a gauss (Url-4).

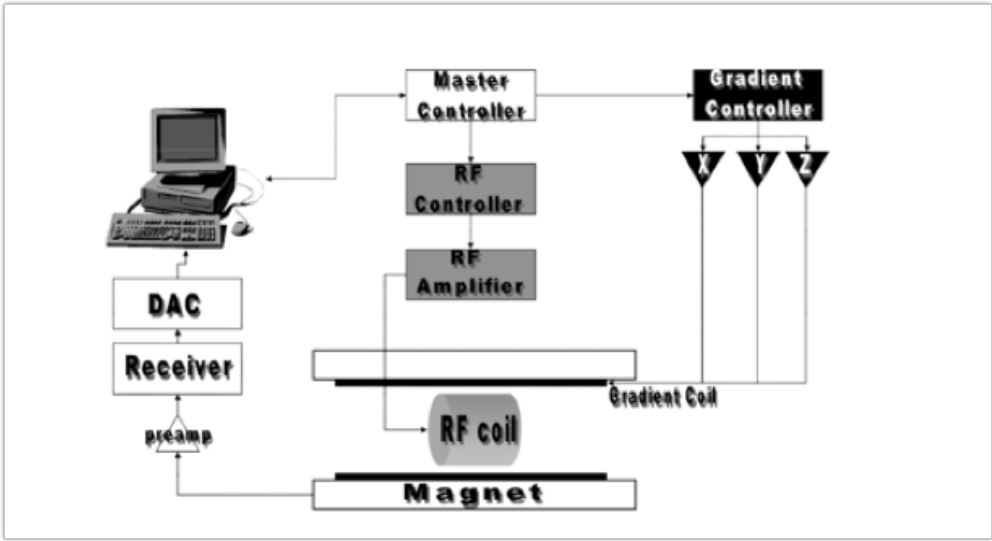


Figure 1.4: Illustration of the main devices.

Source: Url-6

Though an MRI system is quite complicated, the inherent imaging fundamentals of such a system are somewhat simple, particularly in the signal processing perspective. The imaging procedure entails forward, and inverse Fourier transforms as shown in Figure 1.5 (Url-4)

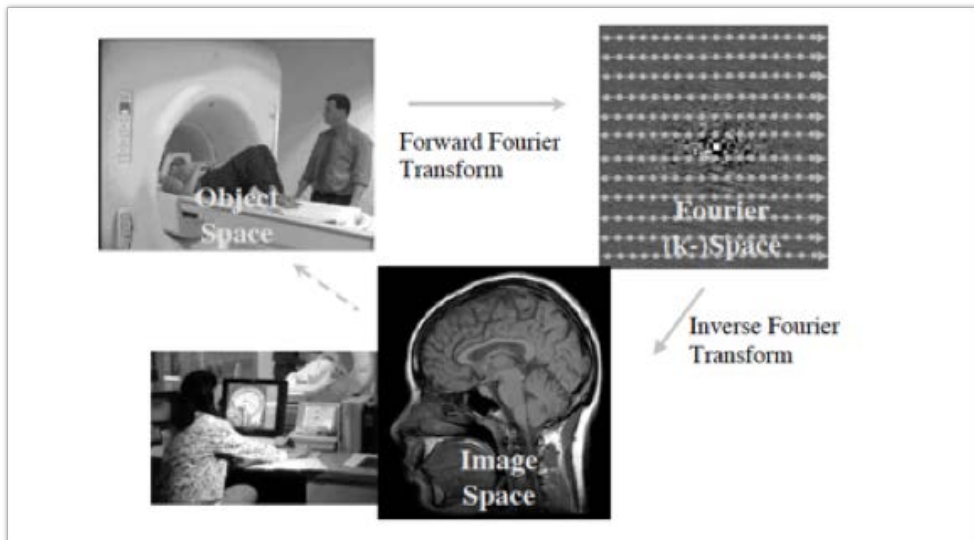


Figure 1.5: the MR imaging process.

Source: Url-6

The imaging procedure doesn't entail the use of ionizing radiation and thus doesn't have the related potential damaging results.

There are two applications for MRI:

1. Diagnostic: Find unhealthy tissue in the body, locate tumors, bone injury, evaluate condition of anesthesia, tissue prep
2. Research: Neuroscience determine connections between pictures and ailments, Cancer, Understand the way the mind functions doing tasks (F. Sadjadi, 2005).

1.5 The Outline of Thesis

This thesis consists of 5 chapters, each chapter is fully overviewed and arranged as follow. The title of chapter 1 is the introduction in this chapter we briefly explained the CT and MRI imaging. The title of chapter 2 is wavelet transform in this chapter we discussed the wavelet and all type with all their figures and, we discussed the wavelet transforms and all of these transform types and some application of wavelet transform. The title of chapter 3 is image fusion in this chapter all the concepts of image fusion that how the image fusion research evolution, techniques which are very common in image fusion and what are the advantages and disadvantages of image fusion have been discussed and some

application and uses of image fusion . chapter 4 is about digital registration theory and image registration classification. in chapter 5 is the conclusion in this chapter we give a brief conclusion of work that we have done, and some propose work for researchers.

2. WAVELET TRANSFORM

2.1 Introduction

The ideal definition of wavelets in computational dictionaries that cut data into parts of frequencies differ from each other and examine each part of these data to later study each component in whether it matches the scale. They've rewards over conventional Fourier techniques in assessing physical conditions in the sign comprises discontinuities and sharp endings. Wavelets had been made individually by disciplines of mathematics, quantum physics, electric engineering, and seismic geology. Interchanges amongst these regions through the last ten decades have contributed to Plenty of fresh wavelet apps like film compression, turbulence, individual vision, radar, along with earthquake prediction (Url-5). In traditional Fourier transform, we utilize sinusoids for foundation purposes. It may supply the frequency info. Temporal data are missing in this transformation procedure. In certain programs, we will need to be aware of the frequency and interim info in precisely the exact same moment. It may be demonstrated which can be obtained rectal and frequency info at this sort of change using wavelets. Additionally, pictures are essentially matrices. Because of this, image processing could be considered matrix processing. visual nature of the human being is more sensitive to the low frequency signals than the high marks. Therefore, we observe that the sensitivity in the brightness and the color of the small copies is shown. This indicates that when the pressure of the high frequency is compressed in the picture, we will get a picture without distortion, (Url-5), the wavelet transforms one of the best applications in image Processing to detrain the low and high frequency area. This chapter introduces wavelets and describes all wavelet kinds, then I explain all wavelet transform techniques, and finish with Wavelet Reconstruction and some interesting applications.

2.2 Wavelet Analysis

We can characterize wavelets as a pulse-like waveform and use an amplitude that starts at zero and then increases and then returns to zero. It likely to arbitrary and unsymmetrical and contains a mean value of zero (Url-5). A wavelet is a function with zero average:

$$\int_{-\infty}^{+\infty} \varphi(t) dt = 0 \quad (2.1)$$

Where $\psi(t)$ is the wavelet function (i.e. the mother wavelet) and $\varphi(t)$ scaling function (also called father wavelet) in the time domain. The wavelet function is essentially a band pass filter and then scaling it to every level plier its own bandwidth, these days, many sorts of wavelets are cited. Each with various personalities and can be used in various programs, we'll clarify it in this section.

2.2.1 Haar wavelet

Haar wavelet is sequential "square-shaped" functions. It's detached, also it like a measure function, figure 2.1 shown haar wavelet (F. Sadjadi,(2005)).

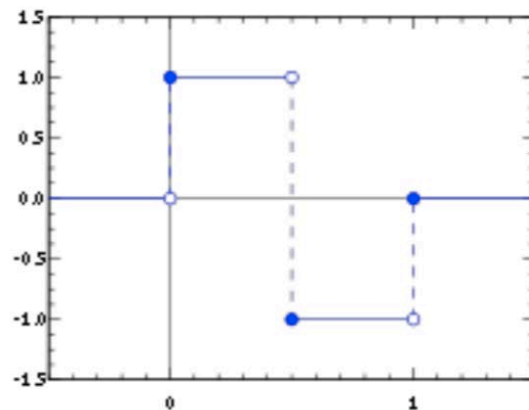


Figure 2.1: Haar wavelet.

Source: Hongmei Zhu, (2011)

2.2.2 Daubechies wavelets

The Daubechies wavelets rely on Ingrid daubechies, which really are a maximum amount of “vanishing moments” for any given support. The titles of the daubechies family wavelets are composed dbN, where N is the arrangement and db that the “surname” of this wavelet figure 2.2 shown daubechies wavelet (Url-5).

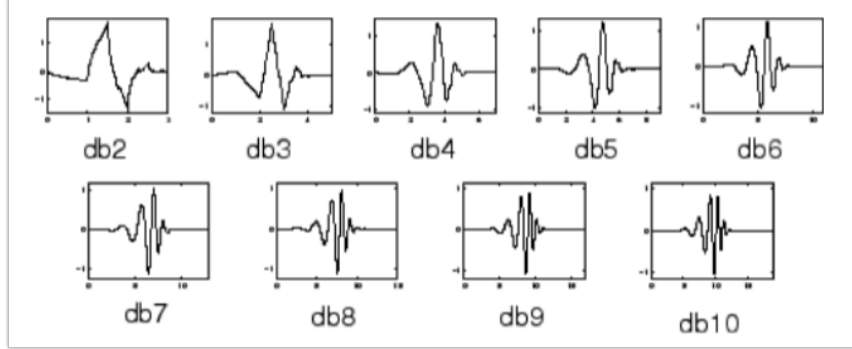


Figure 2.2: The Daubechies family Wavelets.

Source: Hongmei Zhu, (2011)

A good deal of different sorts of wavelets is made to boost the Haar wavelet transform. is defined as:

$$\phi_{r,j,k}(x) = 2^{j/2}\phi_r(2^jx - K), j, k \in \mathbb{Z}. \quad (2.4)$$

where $\phi_r(x)$ in $L^2(\mathbb{R})$ own this characteristic $\{\phi_r(x - k), j, k \in \mathbb{Z}\}$ is an orthonormal sequence in $L^2(\mathbb{R})$ Here, j is the scaling index, k is the shifting index a function $f \in L^2(\mathbb{R})$ is defined as

$$f_j(x) = \sum_k \langle f, \phi_{r,j,k} \rangle \phi_{r,j,k}(x). \quad (2.5)$$

The fluctuations are defined by:

$$d_j(x) = f_{j+1}(x) - f_j(x) \quad (2.6)$$

In order to obtain an analysis of these details on a specific scale we will define $\psi_r(x)$ With similar feature of $\phi_r(x)$ described above (Hongmei Zhu, (2011)).

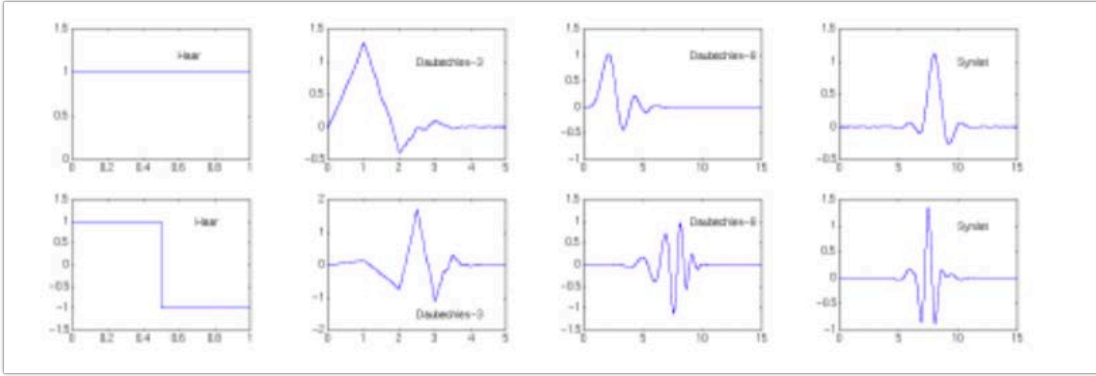


Figure 2.3: First row: father wavelets $\phi_r(x)$, Second row: mother Wavelets $\psi_r(x)$

Source: Hongmei Zhu, (2011)

$\phi_r(x)$ and $\psi_r(x)$ and known as father wavelet and mother wavelet, in figure 2.3, many shapes of the mother wavelet are shown in the equation 2.4. These equations were extracted by working on the change in time and volume of the wavelet father.

ψ_r has the compact support interval $[0, 2r + 1]$

ψ_r has about $r/5$ continuous derivatives

$$\int_{-\infty}^{+\infty} \psi_r(x) dx = \dots = \int_{-\infty}^{+\infty} x^2 \psi_r(x) dx = 0 \quad (2.7)$$

Daubechies 'wavelets deliver effects in image processing on account of the aforementioned attributes. One of the functions of this wave could be compressed readily implemented by span filters. Additionally, service empowers spatial domain localization. Considering that the mother wavelets have been utilized to describe specific properties this signal should contain zero key, so the info is saved from these transactions are the father wavelet (Hongmei Zhu, (2011)).

2.2.3 Mexican hat wavelet

This type of wavelet does not contain scaling purpose and can be derives from a purpose that's commensurate to the 2nd derivative use of the Gaussian probability density function (Hongmei Zhu, (2011)). is defined as:

$$g(t) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-t^2}{2\sigma^2}}$$

Which is

$$\varphi(t) = \frac{1}{\sqrt{2\pi\sigma^3}} \left[e^{\frac{-t^2}{2\sigma^2}} \left(\frac{t^2}{\sigma^2} - 1 \right) \right]$$

It is shown in Figure 2.4

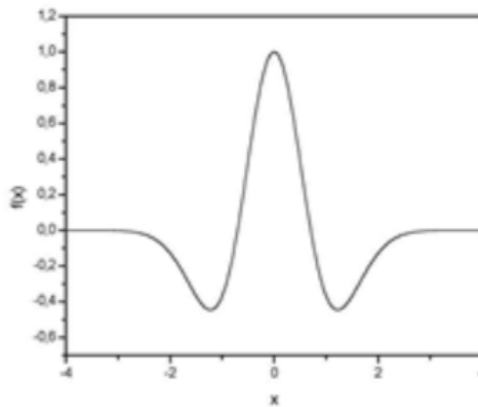


Figure 2.4: Mexican Hat Wavelet.

Source :S. Mallat (1999)

2.2.4 Biorthogonal wavelets

This wavelets dissident from linear phase, which is required to get image and signal reconstruction, shown in figure 2.5

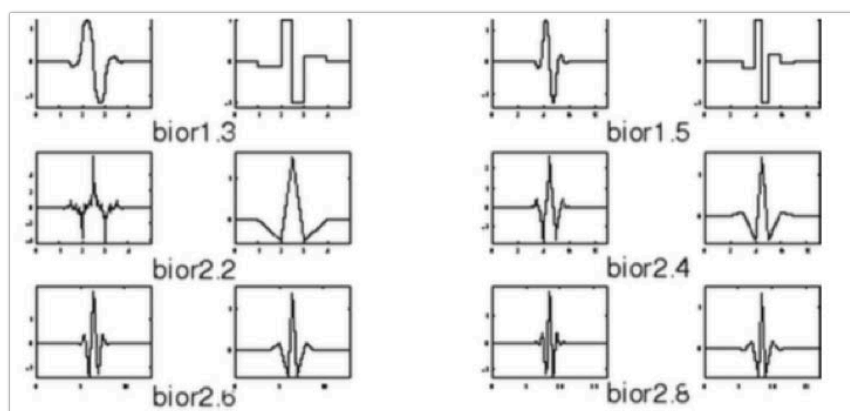


Figure 2.5: The Biorthogonal family of Wavelets.

Source: J. J. Ding and N. C. Shen, (2008)

2.2.5 Symlets wavelets:

The symlets are nearly symmetric wavelets signaled by daubechies as alterations to the db family. The qualities of both wavelet families are similar (J. J. Ding and N. C. Shen, (2008)) , shown in figure 2.6

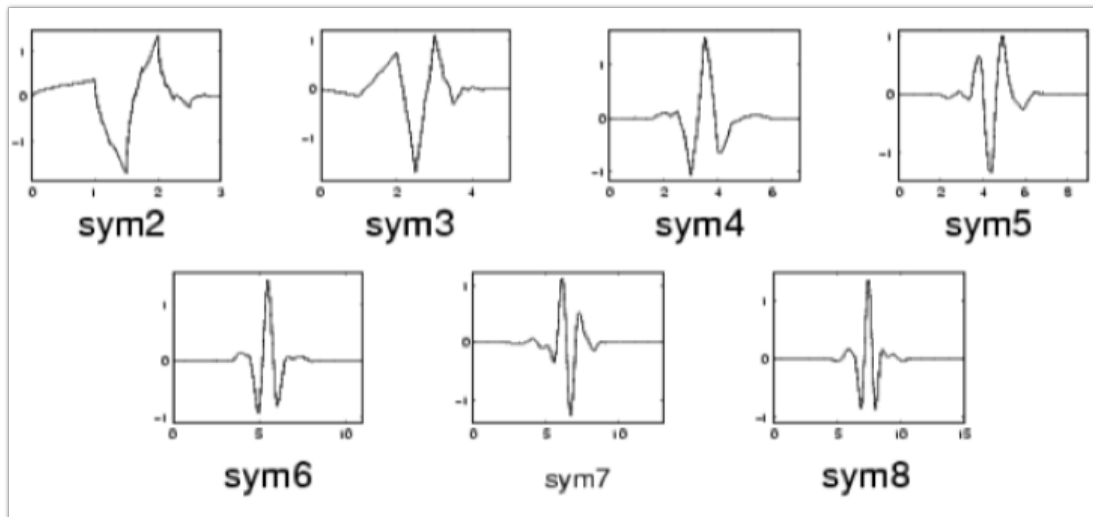


Figure 2.6: The symlets family of wavelets

Source: J. J. Ding and N. C. Shen, (2008)

2.2.6 Morlet wavelet

Cwt often used morlet wavelet, it's defined as after in frequency and time domain:

$$\varphi(t) = \pi^{-1/4} e^{imt} e^{-t^2/2} \quad (2.8)$$

$$\varphi(\omega) = \pi^{-1/4} \mathcal{U}(\omega) e^{-(\omega-m)^2/2} \quad (2.9)$$

Where U measure function and is an adjustable parameter of wave number which enables a precise signal reconstruction.

2.2.7 Shannon wavelet:

The Signal analysis by Perfect pass-band filters Specify a decomposition Called shannon wavelets (LigiaChiorean, Mircea-Florin Vaida, (2009)):

$$\varphi(t) = \text{sinc}(t/2) \cos(3\pi/2) \quad (2.10)$$

$$\varphi(f) = \begin{cases} 1, & 0.5 \leq |f| \leq 1 \\ 0, & \text{otherwise} \end{cases} \quad (2.11)$$

The shannon wavelets in time and frequency domain are shown in figure 2.7.

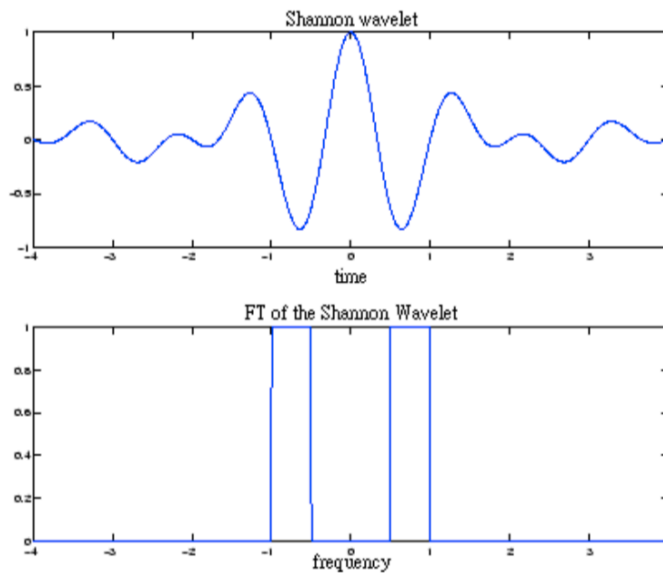


Figure 2.7: The shannon wavelet in time and frequency domains.

Source : Z. Zhang and R. S. Blum (1995)

2.3 Wavelet Transform in Image Fusion Techniques

2.3.1 Continuous wavelet transform

Continuous wavelet transform is defined as the sum of product of multiplying the reference time in a converted form (R. Johnson Suthakar, J.Monica Esther M.E, D.Annapoorani, F.Richard Singh Samuel (2005))

$$W\{f(\mu, s)\} = (f, \varphi_{\mu, s}) = \int_{-\infty}^{+\infty} f(t) \frac{1}{\sqrt{s}} \varphi^*\left(\frac{t-\mu}{s}\right) dt \quad (2.12)$$

where s = scale factor by which the wavelet is compressed or stretched
 μ = time shifting factor by which the wavelet is advanced or delayed.

Scale and frequency: The larger scales correspond with the numerous “extended” wavelets. The farther extended the wavelet, the greater the part of this signal by which it is being compared, and thus signal has been quantified by the wavelet coefficients. Thus, there is a correspondence between wavelet frequency and also frequency as exhibited by wavelet analysis:

Low scale $s \rightarrow$ Compressed wavelet \rightarrow Rapidly changing details \rightarrow High frequency

High scale $s \rightarrow$ Stretched wavelet \rightarrow Slowly changing, coarse features \rightarrow Low frequency

Steps for obtaining the continuous wavelet transform (CWT) of a function: Have a wavelet and compare it into some segment at the onset of the first sign. Compute a number, C , which reflects how closely connected the wavelet is on this particular section of this sign. The greater C is the greater the similarity. More importantly, in the event the sign power and the wavelet energy will be equal to one, C may be interpreted as a correlation coefficient. Be aware that the outcomes will be based on the form of the wavelet you decide on.

1. Shift the wavelet to the right and repeat steps 1 and 2 until you've covered the whole signal.

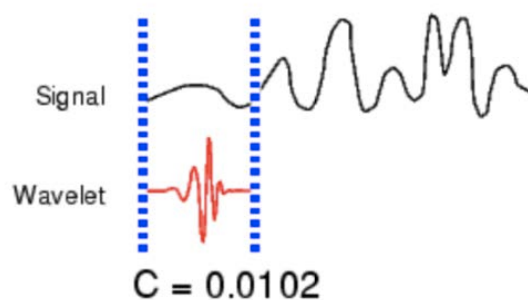


Figure 2.8: Calculation of CWT.

Source: S. Mallat (1999)

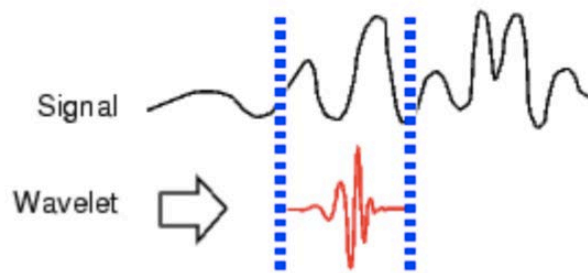


Figure 2.9: Shifting Operation.

Source: S. Mallat (1999)

2. Scale (stretch) the wavelet and repeat steps 1 through 3.
3. Figure 2.9: Scaling Operation

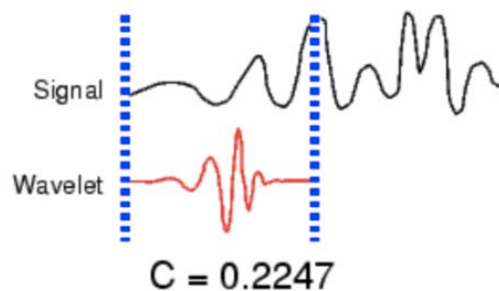


Figure 2. 10: Scaling Operation.

Source: S. Mallat (1999)

4. Repeat steps 1 and 4 for all scales.

CWT can function at just about every scale, from this of their initial signal up to a scale. Even the CWT can also be continuous regarding changing: throughout computation, the assessing wavelet is changed smoothly across the complete realm name of this tested perform.

2.3.2 Discrete wavelet transform

The discrete wavelet transform DWT can be spatial frequency decomposition It can supply multi-phase analysis in 1 measurement the objective of the wavelet transform would be always reflect the exact signal for a superposition of both

wavelets. In case a different sign is represented by $f(t)$ its own wavelet decomposition is subsequently:

$$f(t) = \sum_{m,n} c_{m,n} \psi_{m,n}(t) \quad (2.13)$$

Where $\psi_{m,n}(t)$ is the translated version of the mother wavelet

Wavelet supplied from the equation

$$\psi_{m,n}(t) = 2^{-m} \psi(2^{-m} t - n) \quad (2.14)$$

Where n and m are integers at each scale, $a_{m,n}$ and $a_{m-1,n}$ describe the approximations of the function (f) at resolution 2^{m-1} respectively, while the coefficients $c_{m,n}$ describe the difference between one approximation and the other. In order to obtain the coefficients $c_{m,n}$ and $a_{m,n}$ at the measurement function is defined in the equation 2.14 and this evidence can be used for each position and measurement. The convolution scaling function with all the hint will be executed at every scale Throughout the pragmatic Design of This signal using a low pass FIR h_n filter The approximation coefficients $a_{m,n}$ at every scale is available with the following recursive relation

$$a_{m,n} = \sum_k h_{2n-k} a_{m-1,k} \quad (2.15)$$

Where the best level $a_{0,n}$ is that the sampled signal. Additionally, by utilizing a connected to pass FIR filter g_n .

$$c_{m,n} = \sum_k g_{2n-k} a_{m-1,k} \quad (2.16)$$

Requires re-creation of the original signal that the study filters could also be selected from the biorthogonal set That Has the affiliated collection of filters. These synthesis filters \check{h} and \check{g} could be utilized to absolutely rebuild the signal working with the reconstruction formulation

$$a_{m-1,l}(f) = \sum_n [h_{2n-1} \widetilde{a_{m,n}(f)} + g_{2n-1} \widetilde{c_{m,n}(f)}] \quad (2.17)$$

Equations 2.15 and 2.16 are employed by filtering and following down-sampling. Conversely equation 2.17 is executed through an original up sampling

plus another filtering. A single point wavelet synthesis and evaluation in 1 measurement is in figure 2.11

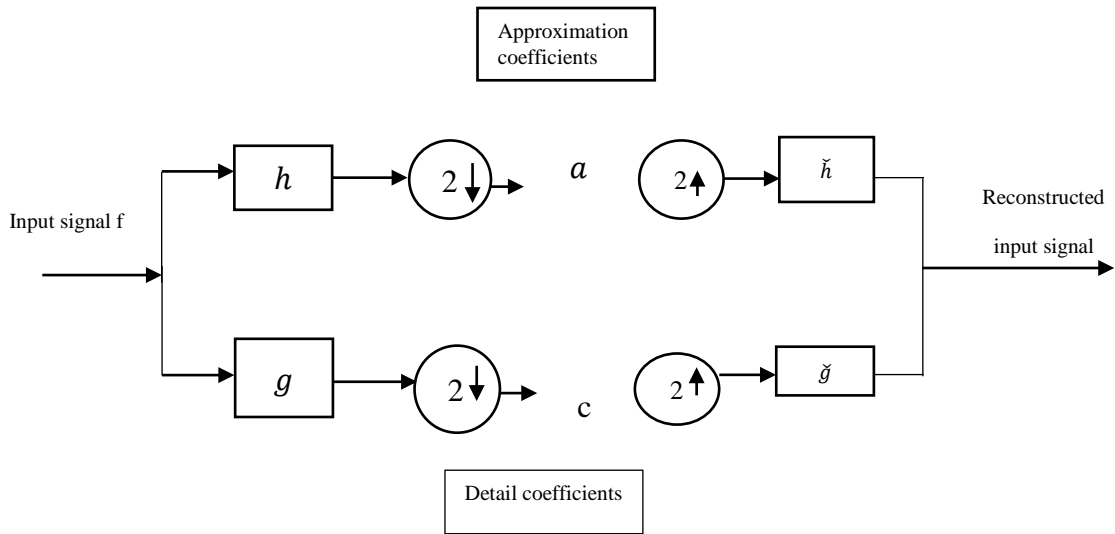


Figure 2.11: one dimensional wavelet analysis and synthesis.

Source: Dhirendra Mishra, (2016)

To expand the wavelet into just two dimensions. It's simply critical to scrub and down-sample from the flat and vertical instructions. It creates 4 sub-bands at every scale. Denoting the horizontal frequency and also the perpendicular frequency adjoining. From recursively employing the particular exact same approach in to the amount 2.12(a) At each and every scale which the sub groups are allergic to frequencies in the scale along using all the LH. HL and HH sub-rings are more vulnerable to horizontal, vertical and angled frequencies Figure 2.12(b)

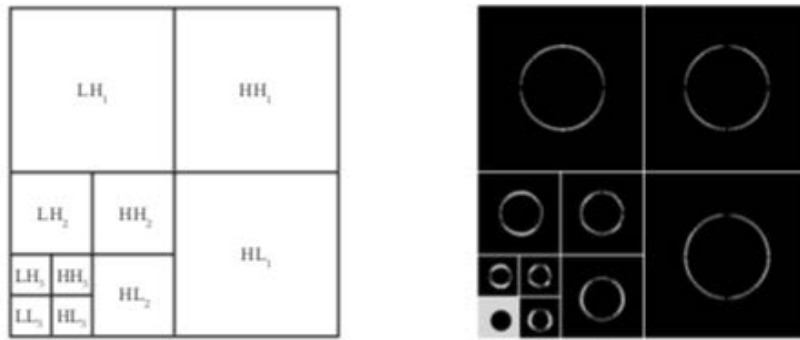


Figure 2. 12: A) magnitude of DWT of black circle B): Magnitude of DWT of black circle on white back ground.

Source: Dharendra Mishra, (2016)

The fusion process of 2 pictures using the DWT is exhibited in figure 2.12: C. Both pictures can be used in a multi-focused groupie. two images of precisely the exact identical view every having an alternative camera attention. The figure explains the coefficients of every change have significantly distinct magnitudes inside the areas of differing attention. An easy "maximum Choice" strategy was utilized to create the combined coefficient map areas inside the image.

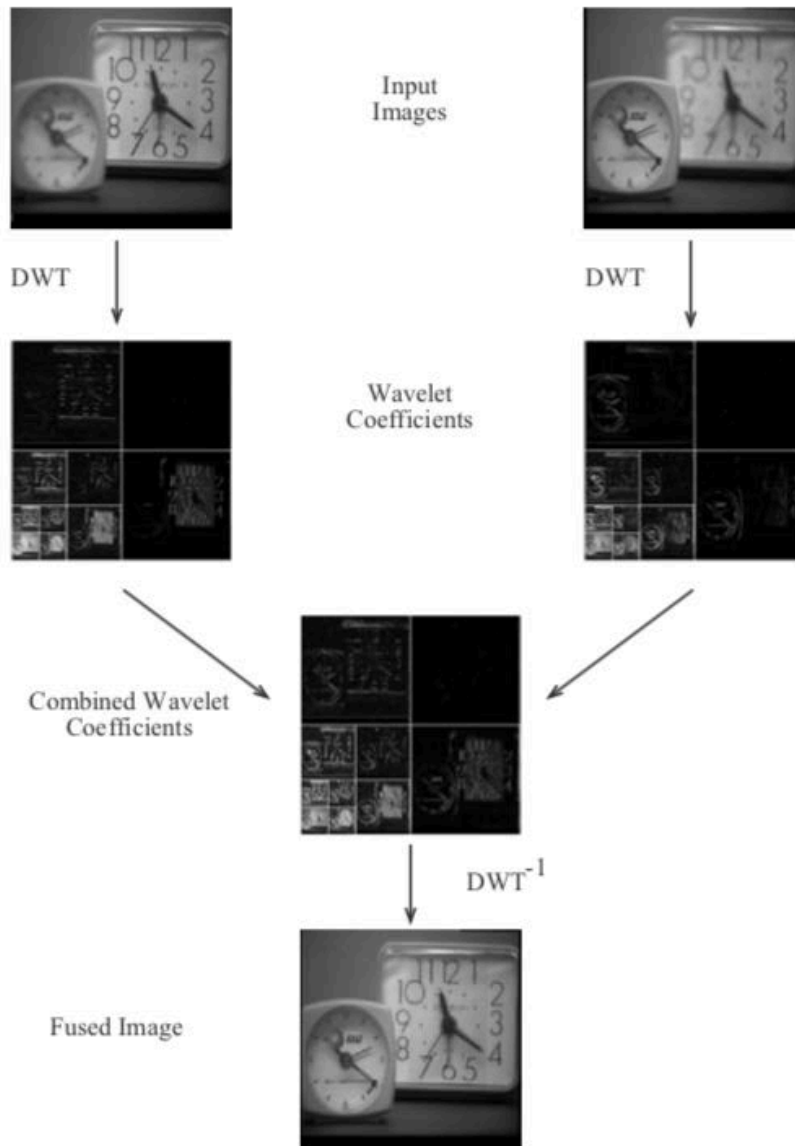


Figure 2.13: C): the image fusion using the DWT and Two Registered multifocuse clock image.

Source: Dharendra Mishra, (2016)

2.3.3 2-D Discrete wavelet transform

The two-dimensional wavelet transform can be used to compute the wavelet transform of matrices. In addition, it can be used on images as an image is essentially a matrix of pixel values. The algorithm for calculating 2-D DWT is

like the one-dimensional case. This chart describes the simple decomposition measures for image Figure 2.13, Figure 2.14:

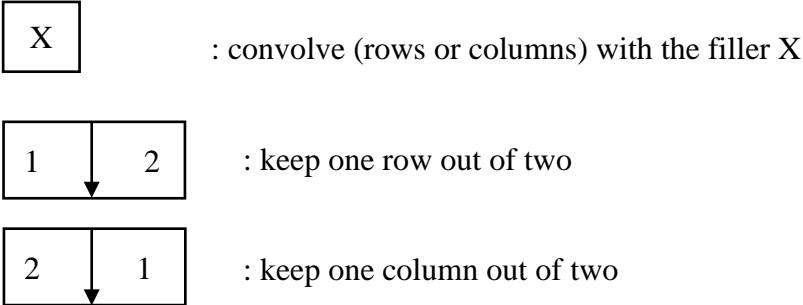


Figure 2. 1 : A): Calculation of approximate and detailed coefficients of 2D DWT.

Source: Yi Zhou, (2005)

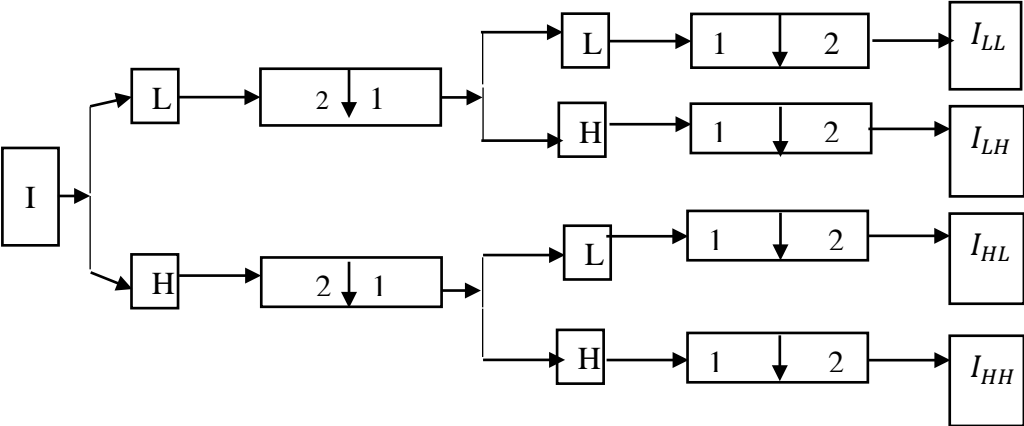


Figure 2. 14: B): Calculation of approximate and detailed coefficients of 2D DWT.

Source: Yi Zhou, (2005)

The decomposition of a matrix or image results in four elements: a single approximate element, (LL) and three particulars elements in 3 orientations (LH, HL, HH) (horizontal, vertical, and diagonal). so that one sign is broken down to several lower settlement parts (S. Mallat (1999)).

2.4 Wavelet Reconstruction

The process of getting the initial sign in the approximation and coefficients with no losing the data is known as wavelet reconstruction or inverse wavelet transform is shown in Figure 2.15. Where wavelet analysis entails filtering and down-sampling, the wavelet reconstruction procedure is composed of up filtering and sampling. Up-sampling is the procedure of directing a sign element by adding zeros between samples. (S. Mallat,1999).

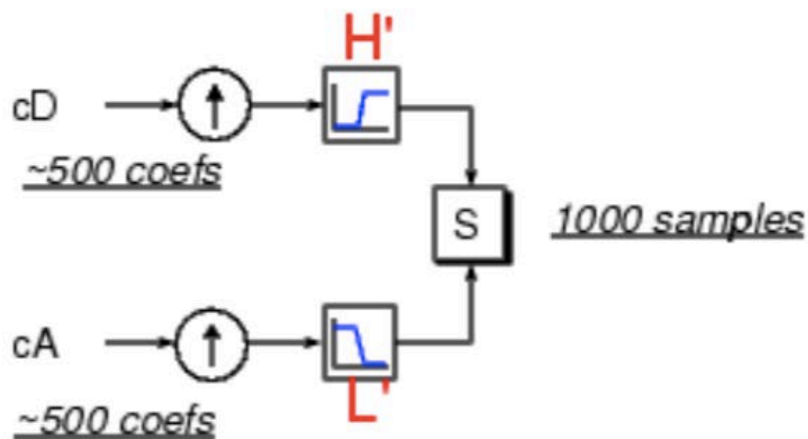


Figure 2. 2: Inverse Wavelet Transform.

Source : Mamta Sharma ,(2012)

2.5 Applications of Wavelet Transform

To conquer this settlement difficulty a wavelet transform can be used to rebuild the signal into a load of wavelets being added together. Wavelets are useful since they're restricted in frequency and time. Wavelets are a potent analytical app which could possibly be properly used to get a huge selection of software, specifically suggest processing, information compression, and design and picture denoising, fingerprint affirmation. Biology: for both cellular tissue recognition, to tell apart the ordinary from the bronchial membranes, for example as DNA analysis, protein analysis, blood pressure, heartrate and ECG analyses in meta outline, such as creating the job dimension and industrial oversight of gearwheel, address recognition, computer images, along with multifractal investigation wavelets can be utilised productively in numerous

fields of geophysical study. Orthonormal wavelets, by means of example, are employed into this test of atmospheric coating turbulence. Wavelets Also Have been utilized to examine Sea Floor bathymetry and also even the topography of the sea ground (LigiaChiorean,2009). Generally, there are two chief methods used in picture owning, the fourier transform and the wavelet transform. The manner by which the fourier transform gets from time to frequency is by devoting time signal to some formulation comprising plenty of $\sin ()$ and $\cos ()$ terms included together. From there a frequency chart can be assembled. The wavelet is a 'mini-wave' while $\sin ()$ and $\cos ()$ are boundless (they never go to zero and remain there, they continue forever). Throughout the fourier transform, the sign is, thus, being deconstructed into waves which are infinitely long. In case you've got a high resolution in the frequency domain (i.e. focusing on a single frequency, such as $\sin(3x)$) it is really hard to isolate it at time, as every frequency is present across all time. Being unsure of this time when focusing on the frequency will be your flip-side of becoming unsure of this frequency when working on time. Instead of a wavelet lasting forever and having no limit in time that's why we used wavelet transform in this thesis, in next chapter we are going to explain what image fusion, image fusion techniques, and methods and the application and uses of image fusion.

3. IMAGE FUSION

3.1 Introduction

Image fusion is a procedure for combining two or more image to improve the data content, and the image fusion techniques are significant as it enhances the performance of object recognition methods by incorporating many resources of satellite, aerial and ground-based imaging systems along with other associated data collections. Further, in addition, it assists in sharpening the images, enhance geometric corrections, improve certain characteristics which aren't visible in both of the images, replace the faulty data, match the information collections for greater decision making. It unites the substantial data from at least two source images into one resultant image which explains the scene improved and keeps helpful information in the input images. Generally, two kinds of vision are categorized. A characteristic closely associated with image quality is attention. Sharp images provide better info than fuzzy image. Nonetheless, in some cases, it isn't feasible to obtain totally concentrated images in only a single camera photo, because some areas seem to be fuzzy because of variations in the thickness of the spectacle and also of the camera lenses focus. This suggests that if the digital camera is based at one thing, the other space of the landscape could possibly be outside of attention. An intriguing way is to shoot more pictures with the desired landscape at the specific very same location, however also with attention located in numerous parts of this spectacle. Afterward, implementing the picture mix thought, all furnish graphics are united, which makes one picture which comprises each one the best-concentrated locations. Picture blend keeps becoming unexpectedly famous in electronic picture processing. The absolute most essential aim of any picture blend algorithm is to coalesce each one the crucial visible data out of multiple enter graphics including the resulting picture comprises additional accurate and total data compared to respective origin graphics. The chapter is organized as follows: Section 1 The Evolution of image fusion research, section

2 types of image fusion, section 3 describes the image fusion techniques, section 4 application and uses of image fusion, section 5 advantages and disadvantages of image fusion.

3.2 The Evolution of Image Fusion Research

The good image fusion system has the following qualities. it may preserve the majority of the helpful information of distinct images, it doesn't create artifacts that could distract or mislead an individual viewer or some other subsequent image processing steps, it has to be reliable and powerful. Eventually, it shouldn't discard any salient information included in any of the input images.



Figure 3.1: Image fusion process.

Source: Mamta Sharma ,(2012)

The first growth of image fusion research is simple image fusion which executes the fundamental pixel by pixel associated operations such as addition, subtraction, average, and division. Normally fusion methods that rely on simple pixel operations on the input image values (Mamta Sharma ,(2012)). Now, these operations are clarified:

3.2.1 Addition

The addition is the easiest fusion operation. It operates by estimating the average intensity value of the input images on a pixel-by-pixel basis. The procedure assumes a semantic alignment and needs quite precise spatial and radiometric recovery. The method gets the advantage of curbing any noise that is existing from the input images (Mamta Sharma ,(2012)).

3.2.2 Average

The pixel typical technique has the drawback that it will suppress outstanding image features creating a very low contrast picture using a “washed-out” look. (Mamta Sharma ,(2012).

3.2.3 Subtraction

Subtraction is the match also and can be employed as an easy fusion operator in switch detection calculations.

3.2.4 Multiplication

Multiplication isn't widely utilized as image fusion operators. But, one major image fusion tool where multiplication is employed in Brovey pan sharpening.

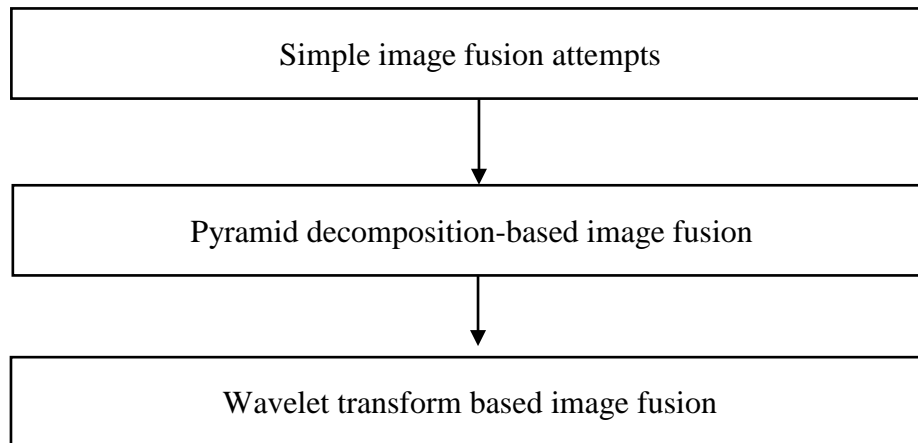


Figure 3.2: evolution of image fusion.

Source: R.Johnson Suthakar, J.Monica Esther M.E, D.Annapoorani, F.Richard Singh Samuel (2005).

The next growth of image fusion study is reprinted decomposition-based picture blend. The crude combination schemes perform the combination directly on the origin images, which frequently have severe side effects like reducing comparison. With the debut of pyramid transform in mid80's, a few complex approaches started to emerge. More recently, along with the development of wavelet theory, Folks Began to Use wavelet decomposition to Choose the Region of Monster decomposition for image Combination figure 3.1 reveal the

growth of image fusion. Truly wavelet transform could be accessed as just one particular kind of pyramid decompositions.

3.3 Types of Image Fusion

Single Sensor: The selection of graphics is fused with each other to develop a brand-new picture with best content. For example, in lighting variant and sound entire environment, a man operator like detector operator may possibly perhaps not need the capacity to discover items of their attention which can possibly be highlighted at the consequent revised picture. The shortcoming of the kind of systems lies below the constraints of the imaging detector which are used in other detection regions. Under the conditions where the machine can function, its dynamic Selection, resolution, etc., are restricted from the competency of this detector by way of instance, a visible-band detector like the digital camera is suitable for brightly lit surroundings like daylight scenes, however, isn't acceptable for badly illuminated situations discovered during night period, or below not fantastic circumstances like in rain or fog.

Multi-Sensor: Exceeds the picture of one sensor picture combination by minding the pictures from several detectors to create a composite picture an infrared camera is accompanying the television and their exclusive graphics are merged to get a revised picture. This approach overcomes the issues known previously. The digital camera Is appropriate for daytime scenes; the infrared camera is appropriate in poorly ventilated surroundings it is utilized in military place, machine vision like in thing discovery, robotics and medical imaging. It is used to tackle the unite advice of many pictures.

Multi-view Fusion: this image has different or multiple views at precisely the exact same moment.

Multimodal fusion: images from various versions such as panchromatic, multispectral, visible, infrared, remote sensing. Typical procedures of image fusion, Weighted averaging pixel-wise, mix in transform domain picture level mix. **Multi-focus Fusion:** pictures from 3d perspectives with its own focal length. The original picture can be divided into regions for example each and each place is responsible for a minimum of one place of the picture (R.Johnson

Suthakar, J.Monica Esther M.E, D.Annapoorani, F.Richard Singh Samuel (2005)).

3.4 Image Fusion Techniques and Methods

3.4.1 Introduction

Generally, fusion techniques may be divided into various levels:

1. Signal level mix in sign-based fusion, signals from various detectors are combined to make a new sign with a much better signal to noise ratio compared to originals signals.
2. Pixel/Data level combination is the mix information from several sources in individual resolution information, that is anticipated to be informational to either of the input or show the changes involving info sets obtained at various times.
3. Feature level fusion extracts different attributes, from various information collect sources and merge them into a single source or more attribute maps which might be used rather than the original information for additional processing. It utilized as input preprocessing for image segmentation or change detection.
4. Decision level fusion combines the results from many algorithms to create a final revised choice (J. Lanir, et al. (2007)).

A lot of image fusion methods which have been analyzed and developed but every new method based on the common characteristics on basics method so far are as follows:

3.4.2 The brovey transform image fusion

The BT relies on the chromaticity transform. It's an easy way of combining data from several detectors with the restriction that only 3 bands are included. Its goal is normalizing the 3 multispectral bands taken for RGB display also to multiply the consequence in every desired advice to create the brightness or brightness part to the image, this technique requires an experienced analyst for its pacific adaptation of parameters. The Brovey Transform was designed to avoid the downsides of this multiplicative method. It's a mix of arithmetic operations and normalizes the spectral bands until they're multiplied together with the panchromatic image.

3.4.3 High pass filtering

The high resolution multispectral images are obtained from high pass filtering. The high-frequency data in the high resolution panchromatic image is inserted into the minimum resolution multispectral picture to find the subsequent picture. It's completed by obeying the high-resolution Panchromatic picture with a high pass filter or simply by carrying the very first HRPI and subtracting LRPI out of this. The spectral information comprised at the Specific Low frequency information of this HRMI is maintained via this procedure (Z. Zhang and R. S. Blum,1995).

3.4.4 Artificial neural networks

Artificial neural networks (ANN) have found their importance of pattern recognition. Within this kind of nonlinear response, the purpose is used. It uses a pulse coupled neural network (PCNN) which is composed of a comments system. This system is separated into three parts namely the open area, the modulation area, along with the pulse generator. Each neuron corresponds to the pixel of the input picture. The pixel strength is used as an outside input to the PCNN. This process is valuable concerning hardness against noise, liberty of geometric variations and also the capacity of bridging minor intensity variations in input routines. PCNN has biological importance and used in medical imaging since this course of action is possible and supplies real-time system performance (Z. Zhang and R. S. Blum,1995).

3.4.5 Principal component analysis

PCA transformation is a method out of data for bettering a data collection. It was created by Pearson 1901 and Hotelling 1933, although the finest modern benchmark is Jolliffe, 2002. The purpose of the technique is to decrease the dimensionality of multivariate information whilst maintaining as much of the pertinent information as you can. PCA data are frequently more interpretable than the source information. By utilizing this process, the redundancy of the image data could be diminished. The PCA involves a mathematical process that transforms many Connected factors into many uncorrelated variables called principal elements It simplifies a more streamlined and best description of this information collection. The first key element Must be along the trail with the most variance

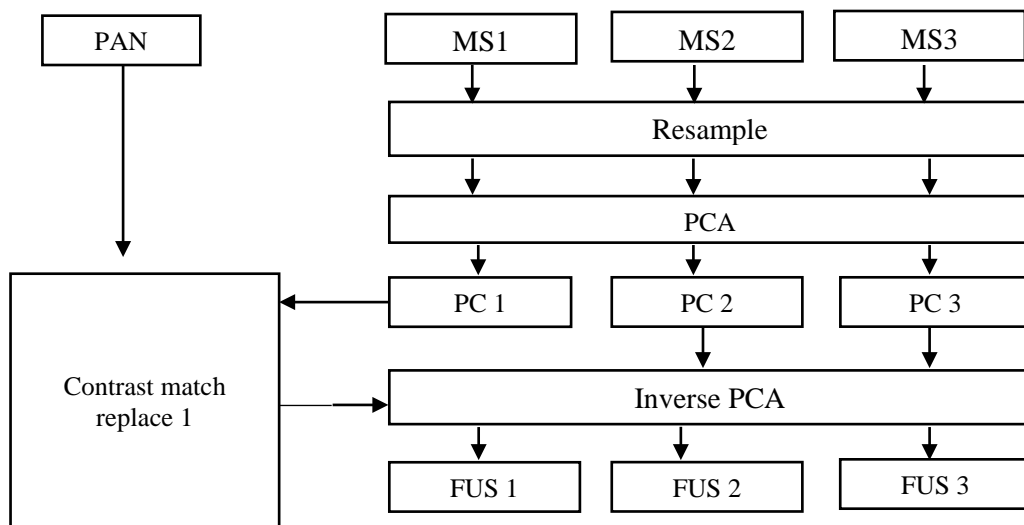


Figure 3.3: Block scheme of the PCA fusion method.

Source: J. Lanir, et al. (200

The next principal element is bound to lie at the sub space vertical with the very original. Through this sub space, this part factors that the management of highest variance. The 3rd main part would be that the absolute most variance direction from the sub space vertical for the initial along with The PCA might even be termed Karhunen Loeve shift or also the Hotelling shift. The PCA will not need a pre-determined collection of carrier's vectors, along with wavelet etc. From the combination process, the PCA system generates an interconnected and harmonious image (PC1, PC2.... PCn, in which n is amount of entered Multi-spectral packs. Afterward, reverse PCA transformation is employed to acquire color RGB shown in the picture is annotated in the figure3.

3.4.6 Intensity-hue-saturation (ihs)

IHS is a common way of fusing high spatial resolution, single band, pan and low spatial resolution, multispectral remote sensing image. The R, G and B rings of the multispectral image are changed into HIS parts, substituting the intensity element by the pan image, and executing the reverse transformation to acquire a high spatial resolution multispectral image (see figure 3.4). HIS can improve spatial specifics of the multispectral image and enhance the textural features of the fused, but the fusion image exists serious spectral distortion. The

HIS change can be used for geologic mapping since the IHS Change could allow varied forms of spectral and spatial landscape Data to set for analysis

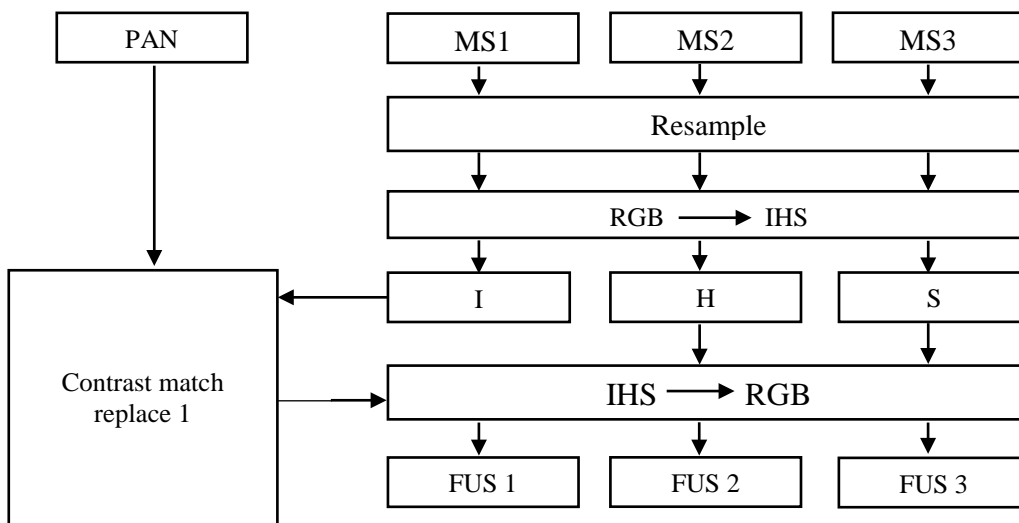


Figure 3.4 : Block scheme of the IHS fusion method.

Source: J. Lanir, et al. (2007)

The color disfigurement of HIS technique is important. To decrease the color disfigurement that the PAN density has been matched in the picture element are extending before the reverse change. Image blend based on the non-sub-par Contourlet change (NSCT) and HIS attained increased in keeping the spectral data and spatial information and better integration impact. With HIS change, the section-based fusion was designed especially or spectral features maintaining image merge combined using a spatial domain filtering (Z. Zhang and R. S. Blum,1995).

3.4.7 Multi resolution analysis based method

The multiresolution analysis is just most promising approaches in image processing. The MRA theories were intimated by Meyer and Mallat, which gives a natural frame for the comprehension for wavelet and pyramid change foundations. The researchers categorized the multiresolution in two ways, they're low resolution and higher resolution. The vector space contains another vector space its higher resolution. Each vector space contains all vector spaces that are of low resolution

3.4.8 Pyramid transformation

Various sorts of pyramid decomposition are utilized or designed for image combination like a ratio of non-pass pyramid, gradient pyramid, laplacian pyramid. Pictures pyramids is a multiresolution evaluation variant. The basic idea is to construct the volcano change of this revised picture in the pyramid transforms From the foundation picture after which fused picture is accessed from simply taking reverse pyramid transform. It may offer both frequency and spatial domain localization.

It may offer advice on the contrast affects and the human visual system is particularly sensitive to those sharp contrast adjustments.

The basic principle of laplacian analysis of the source image is to create composite representation and reconstruct the image by integrating these analyzes and eventually rebuild the revised image by doing an inverse pyramid Change. Schematic diagram of the laplacian pyramid fusion method is shown in figure 3.2.

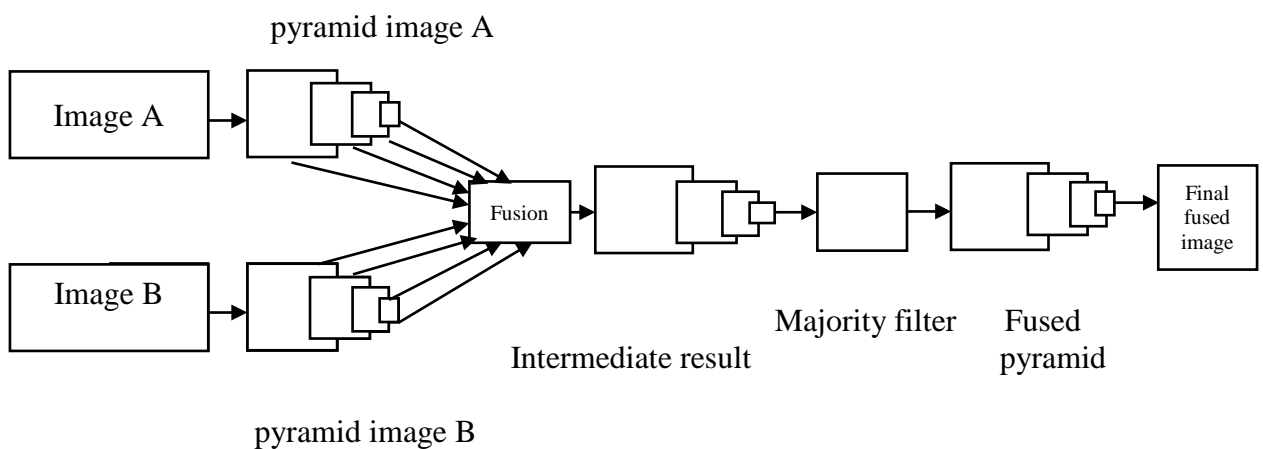


Figure 3.5: Block scheme of the Laplacian Pyramid fusion method.

Source: R. Johnson Suthakar, J.Monica Esther M.E, D.Annapoorani, F.Richard Singh Samuel (2005)

Laplacian Pyramid used several modes of the mix like averaging or selection. From the first one, the mixing procedure chooses the part pattern in the origin and Copies it to the combination pyramid, while discarding the routine. At the next one, the procedure averages the resources patterns (J. Lanir, et al. (2007)).

3.5 Application and Uses of Image Fusion

Basically, used in satellite or remote place for its ideal perspective of satellite eyesight it should use in medical imaging. Picture blend employed in military regions in which all of the viewpoints used to discover the dangers along with other settlement work-based performance. For devices vision, it's effortlessly utilized to envision states subsequent to a picture concludes its excellent to your eyesight. In robotics discipline falsified pictures mostly employed to inspect the frequency versions from the perspective of images (J. Lanir, et al,2007)

3.6 Advantages and Disadvantages of Image Fusion

Advantages: It's easiest to interpret. Fused picture is true in color, it's ideal for recognition and identification, it's low in price, it's a high resolution utilized in multiscale images. Through image fusion there's enhanced fused graphics in fog, Picture fusion keeps the capacity to read outward signs in most areas, Picture blend has numerous contrast benefits basically it should improve the picture along with all the views of a picture, it raises the conditional awareness. Picture blend diminished the data storage and information transmission.

Disadvantages: Images have less functionality in unfavorable climate states it often does occur when movie blend is completed with just detector mix procedure, maybe not readily visible during the nighttime its own principal for effect of digicam attributes if it's in daytime or nighttime. Added resource vitality is critical because of its exemplary conversion of mages predicated on plasma frequency," as a result of fog or rain visualization isn't cleared in the event that you simply click both source images within such a kind of climate states that it provides the hardest output. Through this action you'll find tremendous possibilities of info loss, it takes care. Performance of data is still very slow when images have been calibrated (J. Lanir, et al,2007).

In this thesis, we used discrete wavelet transform (DWT) based on image fusion because it provides sufficient information both for analysis and synthesis of the original signal, with a significant the computation time. the DWT is considerably easier to implement when compared to the CWT. In the next chapter, we will explain the image registration which intent is to align images

with respect to each other, The result for this step can help in further analysis processes including image fusion.

4. DIGITAL REGISTRATION THEORY

4.1 Introduction

Image registration is an essential in medical analysis that has gained in twenty decades of evolution. Even the correspondences could possibly be utilized to alter the appearance from rotating, and multiplying, extending etc., of a single picture therefore it closely looks like a somewhat different therefore the place may possibly be directly contrasted, together or examined. The absolute most instinctive use of registration is really to mend for distinct individual regions between notes. Picture registration is not a conclusion by itself adds significance to both images, e.g. by allowing structural and operational images to be witnessed and examined from the specific same unified technique, additionally alleviates fresh applications of images, e.g. to monitor and quantify illness progress together with period affected maybe to create statistically units of structural variant at people (Pelizzari CA, Chen GTY, Spelbring DR, Weichselbaum RR,1989).In some app fields picture enrollment is currently a core unit including as for instance (i) reputable examination of fMRIs with mind demand photograph registration to adjust for more compact a large number of topics matter movement throughout ; (ii) the favorite system of voxel based morphometry employs image enrollment to send brain images outside of tens of thousands of tens of thousands or even numerous themes to an average coordinate process for test (alleged "plasma screen normalization"); (iii) the test of perfusion images of this core could not be potential minus picture enrollment to pay for human respiration; also (iv) a few of the latest MR image acquisition systems include things like picture registration to adjust movement. Traditionally, image-registration has been categorized to be "rigid" (where by images should function as objects that simply must get rotated and interpreted based using just one individual to reach correspondence) or even "on-rigid" .For those apps a stiff system approximation was decent as there is relatively slight

shift at heart position or form in the skull over the relatively brief durations amongst scans. In these times inflexible registration is usually lengthy to comprise affine registration, for example scale factors and shears, and also may partially deal with for calibration openings round gross or scanners gaps in scale amongst problems. Additionally, there were several new reports that protect these areas in far greater depth (Barbara Zitova, Jan Flusser,2003).

4.2 Image Registration Classification

The classification of image registration Methods (P. A. Van Den Elsen, E. J. D. Pol and M. A. Viergever,1993), are summarized and given from the figure 4.1, these methods explained in this chapter.

4.2.1 Intensity-based and feature-based models

Image orientation calculations of both image enrollment process are all categorized to potency predicated and feature established. Inside this course of action, one of those images is named the foundation or routine, with one different man images are called the sensed or purpose or theme graphics. The photograph enrollment is Accessed by way of spatially registering for a target graphics to coordinate together using the reference Graphics From the intensity-based procedures, it's compared hardness routines in graphics throughout significance metrics, and also in feature-based procedures, locates involving graphic lineaments such as things, along with boundaries. Intensity-based systems enroll entire images or sub-images. In case sub-images are enroll, centers of sub graphics are handled as corresponding element factors. Feature-based processes set a correspondence between an assortment of different details in movies notably.

4.2.2 Transformation models

Following the attribute correspondence was shown that the mapping function is assembled. It ought to change the sensed picture into overlay it on the mention. The form of the mapping function has to be corresponded with the supposed geometric disfigurement of this perceived image, into the procedure of image acquisition (e.g. scanner reliant distortions and mistakes) as well as the essential

precision of the enrollment (the identification of mistake to get rigid-body point-based registration has been introduced. In particular circumstances if the geometric disfigurement is partly known, e.g. if a version for this disfigurement due to the apparatus or the geometry, the correction depending on the reverse of the disfigurement could be achieved (by way of instance, in Refs. (Brown Gottesfeld L,1992), The version our entire world's form and spinning the satellite orbit together side all the scanning geometry of this sensor). Examples of communication purposes might be divided to two broad categories centered around the number of image info they make use of because of their services. World wide variations use all CPs for estimating one particular among their mapping job parameters legitimate for that entire photograph. On the flip side, the neighborhood mapping works treat the image for a synthesis of spots as well as the function parameters are based on the positioning of their service from the picture. It contributes into the tessellation of the picture, normally a triangulation, as well as the specifying of parameters of the mapping work for every patch individually.

4.2.3 Spatial frequency domain models

The spatial coefficients in the image processing have a specific function as they operate on the density characteristics of the image are in the frequency field

The algorithms made for feature fitting is somewhat shallow to conventional processes of picture enrollment. Following the number of deal facets surpasses the minimum needed to specify just the perfect conversion version, Consensus and random replication of this algorithm (Mauer C.R., Fitzpatrick J.M.,1993) can likewise be properly used to re-gauge the parameters register the picture.

The algorithm built to detect that the spatial conversion parameters in between source and objective pictures out of the picture registration process drops into spatial-frequency domain variations. These methods, when determining the frequencies of frequency energy, benefit from frequency conversions. The period procedure can be used into a pair of graphics whilst to create a 3rd film which comprises one particular summit from the frequency domain name. The procedure is resilient to sounds, occlusions, as well as different flaws regular of satellite or medical graphics, including a fantastic deal of plasma-domain names. What's more, the purpose correlation employs the speedy Fourier transform method of figure out

the cross-correlation amongst both movies which commonly impacts considerable performance profits.

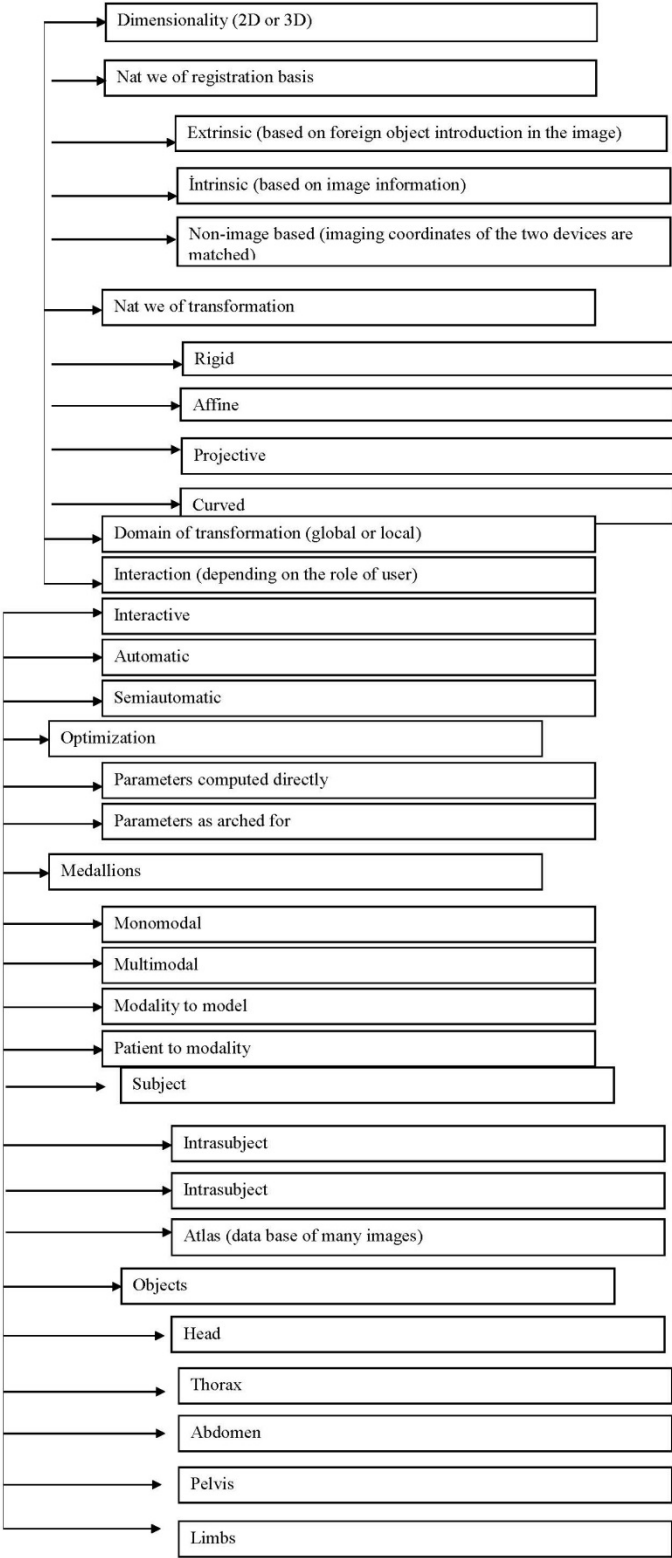


Figure 4.1: Image Registration Classification.

Source :P. A. Van Den Elsen, E. J. D. Pol and M. A. Viergever, (1993)

4.2.4 Mono-multi-modality models

Another method has been classified amongst mono- modality along with multi-modality techniques. In only modality variant the picture is accessed from just the distinct very same scanner, whereas at multi-modality registration procedures the graphics got by multiple sensors or in a few situations. Multi-modality registration procedures include a whole lot of apps in professional medical image evaluation.

4.2.5 Manual, semi-automatic, and automatic models

The tools meant for direct Orientation of origin and target pictures are predicted Guide variations. Semi-automatic variations require validate the correspondence of registration. Interactive technical decrease user bias by executing specific key operations mechanically direct to your registration. Semiautomatic approaches do additional of these enrollment measures automatically but certainly are based up to confirm that the correctness of picture registration treatment. Algorithms that are intended to perhaps not let any consumer together with almost any kind, additionally plays with all enrollment steps mechanically.

4.2.6 Similarity models

The similarity actions listed here will be divides in to two different classes, either the durability or also attribute-based procedures. Predicated around the traits employed, a few pruning steps can possibly be included in each classis. Usually the resemblance measure used for deformable image registration includes 2 phases: a single correlated for this specific voxel strength or structures similarity, and also the other individual into the deformation field hence, the previous similarity step, or expenditure feature, can be tradeoff between the “voxel strength or structures resemblance” along with the constraints levied about the deformation niche. The restriction expression is typically referred to as punishment or regularization time period. Notably in non-rigid registration, the alternative of this relocating and mended images may cause different enrollment outcomes. Such issues have been known as inverse inconsistency and signify that a blunder at least one of the enrollment directions.

4.2.7 Uncertainty models

Uncertainty rendering may be utilized to encode the amount of confidence for different areas in the quantity left scan. Even though this can offer the right summary of how precise particular image regions are, these techniques aren't able to envision multiple doubt standards. As a result, the presented technique is effective at imagining a multi-variate uncertainty area for medical image information. Volume manufacturing using specific transfer purposes to visually encode numerous worth and their similarities each grid are frequently utilized. Even though these techniques offer you the right volume visualization for multi-variate quantity datasets, they may result in visual clutter. To fix this issue, the introduced technique uses an iso-surface established visualization that's embedded into the first picture. Gillmann et al. introduced a visualization which indicates different regions in the picture that reveal exactly the exact same uncertainty (Simonson, K.Drescher, S.Tanner,2007). Their technique uses iso-lines to signify unique regions of uncertainty and embeds this data in the first picture. Their method proves that this permits users to easily comprehend the character of this high-dimensional uncertainty distance and the way it's connected to the input picture.

4.2.8 Optimization models

Optimization denotes the method by the transformation is adjusted to make efficient the photograph resemblance. An awesome optimizer is just one that gently and instantly discovers out the very best likely transformation. adopt a wonderful optimizer a understand this registration dilemma, the restrictions that might possibly be executed and comprehension numeral investigation. In non-rigid enrollment applications design or picking an optimizer could be hard as the additionally non-rigid (elastic) the transformation version parameters are often sought after spelling out it. For the optimizer this commonly suggests that a lot of hours is required to get paid a parameter conclusion and there's possibility of choosing the couple of parameters, that result is a wonderful picture game which is still perhaps not the perfect 1 (the "regional minima" concern). A delicate difficulty is a transformation parameter alternative which offers a wonderful photograph or feature resemblance may possibly perhaps not be significant. The absolute most normal example with the is that when persons

have an previous impression which the registration of a single photograph onto the following should be more diffeomorphic; essentially therefore that whenever the transformation has been implemented into a genuine physical point to replicate it then no loopholes of the item could manifest. The issue is the fact that snapping can usually create a transformation that delivers the graphics longer akin despite it's really being self-evident. So, in many states, serial MR mind registration of an issue under-going diffuse atrophy, there exists an earlier anticipation that a folding or ripping really should not be requested. Often, ripping is really of copyright problems. By way of instance, intrasubject mind registration where by one area comprises a large extrinsic tumefaction along with gut enrollment at which fluid packed spaces can arise and vanish involving scans are all cases by which correspondence is not well-defined and at which fold, or ripping could possibly be crucial that you describe exactly the underlying bodily transformation. Other limits might be signaled at the range of the conversion version, e.g. the conversion needs to take accordance with all the behavior of a deforming adaptive body (Stuart Alexander MacGillivray,2009).

4.2.9 Parametric and non-parametric models

Parametric picture enrollment Approaches predicated on limited collections of attributes or parameters graphic features. A wide selection of mark has been awarded at either the grade and also the template, plus a transformation has been searched which empowers them to match, a quadratic individual, or even maybe another registration. even nevertheless, may cause poorly - formed alternate options, as clarified after. Evaluating the allure of this conversion may possibly become additional valuable. Landmarks, but are tough to mechanically detect Whenever a few automations of mark detecting can be prospective, human intervention could still be demanded, cutting back the liberty of the procedure drastically. Key axes are put forward being an option; the biggest market of the image, as well as all the vectors and its particular important axes lie, are typical readily seen via essential numerical evaluation. Discovering a transformation involving your axes of this cite together side all the template is pretty simple however includes a unique defect. In particular, the principal axes technique holds an excessive amount of vagueness.

The image capabilities might widened add to the full picture, as well as the parameters to enhance might be manipulated. Several procedures confine themselves into affine linear transformations, going to optimize only two or three problems. One of these are a couple utilizing Gauss - Newton techniques, and also a couple of schemes making use of new distance actions.

In non - directional image enrollment, when compared with it has neither pay attention to special points need an affine linear conversion (B. Srinivasa Reddy, B. N. Chatterji ,(2013)). For your gap, the quantity of squared differences is really a popular metric that's instantly calculated within Ω .

$$D [R, T; u] = 1/2 \| R - T u \|^2 = 1/2 \int_{\Omega} (T(x - u(x)) - R(x))^2 dx \quad (4.1)$$

The first measure, on the flip side, may differ broadly with the specific non-parametric procedure utilized. Fundamentally, predicated up on the difficulty to be resolved, appending a punishment time period will be potential in case specified solutions have to be avoided.

4.2.10 Rigid and non-rigid models

Historically, rigid and non-rigid variant classification is found in image registration. In the rigid variations, the images are all assumed to be of things which only have to get rotated and translated to one another to get to the crucial correspondence. Non-rigid models are growth to rigid models by allowing deformations so as to achieve adequate matching. Non-rigid picture registration variations are a lot more general manner than the popular affine and stiff variants however need a great deal of more complicated methodology and computational effort to execute because of its requirement. The aim of non-rigid registration would be with all the picture conversion model. Still, there exists an increasing body of work which focuses around real life uses of non-rigid registration as opposed to specialized refinements, and also non-rigid enrollment style is a vital dependence on employing biomechanical types of human anatomy. Production of production of an ordinary cardiac variation which is instantiated by terminal adaptive enrollment together with high-resolution images of an issue got using over inch imaging modality (Sermesant M, Forest C, Pennec X, Delingette H, Ayache N,2003) . Many methods might nevertheless be considered for picture processing normally and picture analysis

especially. The requirement and requirements of health research are unthinkable
supplied the algorithms that are engineered & processes are verified properly.

5. THE PROPOSED WORK

In this chapter, we are going to explain all the work that we have done to design the program. In the first part, we are going to give a brief introduction of our type of image which used (DICOM), In the second part we are going to discuss Medical Image Fusion Based on Wavelet Transform using DWT method and in the third part we are going to explain Algorithm that we used in our program ,last part we are going to explain the parameters and discuss the result.

5.1 Digital Imaging and Communication in Medicine

Throughout the previous thirty decades, there's been a massive evolution of digital technology. In those days the computers it interferes greatly in our lives virtually every part of the own lives, so they've grown increasingly significant in medical programs. Much medical imaging approaches utilized today largely rely on computer processing. Computers been use not only to display or store images but to create images or 3D models in the input of information. We get information from imaging devices that utilize complex procedures. Additional there's become a big, less or stronger, evolution of computer-aided diagnosis (CAD) methods (R.M. Rangayyan,2005 , J.S.Suri, R.M. Rangayyan,2006) . Due to a lot of instructions in the development of medical imaging equipment, it had been quite vital to developing a standard for link and data flow between appliances. Because there are many manufacturers that provide medical imaging gear with many methods, getting a regular make use of this image and health care information simpler. This standard is created by workgroups annually to satisfy any medical division (L.G. Robers (1963)).

DICOM Standard is composed of numerous layers in respect to ISO OSI system layout. DICOM is different from the surface because it doesn't set a physical connection. Upper layer protocol (ULP) is clarified inside the DICOM standard. It is an abstract protocol that defines data encapsulation and is more than par five of the ISO OSI model. From the software level there are five Chief areas of surgery: Transmission and allocation of all entire things (like for example, pictures, waveforms and newspapers), difficulty along with recovery of the items, performance of certain tasks (like for example), printing pictures on picture),work flow management (assistance of worklists and status facts) and caliber and consistency of photograph overall look (equally for both print and display) (Pelizzari CA, Chen GTY, Spelbring DR, Weichselbaum RR, (1989)). DICOM was intended to create clinical pictures and linked info standardized to get easier inter change. Besides that, DICOM defines network-oriented alternatives for printing or transfer of these images and networking formats such as information market, work flow direction, balancing and also greater grade of demonstration and prerequisites of conformance of apparatus and applications. Info issue definitions (IODs) have been introduced at the norm to specify characteristics that spell out a certain quality with the photograph. IODs possess a well-defined value and also their faculties just clarify the type of this product or service, info of this individual, executed stories or procedures together side the specialized information in regard to the health imaging apparatus applied from the task

5.2 Medical Image Fusion Based on Wavelet Transform

Multimodal medical image fusion algorithms and apparatus demonstrate remarkable accomplishments in enhancing clinical precision of choices based on clinical images. The choice of the imaging modality to get a targeted clinical research demands clinical insights special to organs under study. It's practically not possible to capture each detail from 1 imaging modality that will ensure clinical precision and robustness of the investigation and consequent identification. Figure 5.1 shows the 3 major concentrated areas of research in medical image combination: (a) Identification, improvement and development of imaging modalities useful for medical image fusion (b) Development of different techniques for medical image fusion (c) Application of medical image

fusion for studying human organs of interest in assessments of medical condition

Various approaches are available for graphic mix applications, but image fusion techniques are essentially categorized into two broad classes i.e. spatial domain Fusion and Transform domain-based fusion that we explained the in chapter 3.

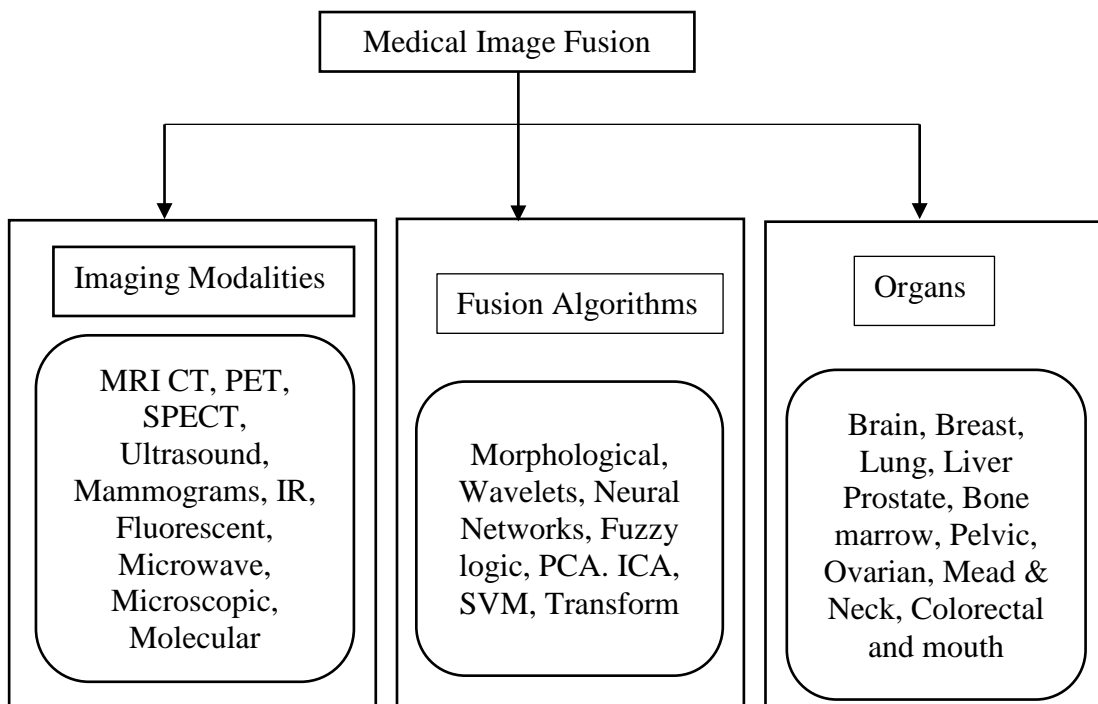


Figure 5.1: Nature of modalities, methods and organs used in medical image fusion

Source: Sermesant M, Forest C, Pennec X, Delingette H, Ayache N. Deformable (2003)

A wavelet transform is really a mathematical that could find local features within a signal. Plus, they can be properly used to combine (2 d) indications like 2-d gray scale graphic signs in to numerous varying degrees for multiresolution examination. Wavelet change was significantly found in a lot of destinations, for example feel investigation, data compression, and feature discovery, and image mix.

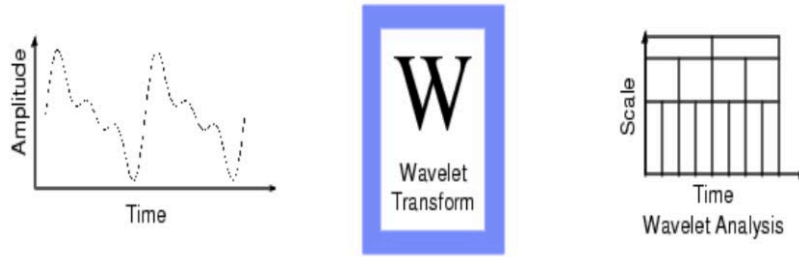


Figure 5. 2: Wavelet Transform on a signal.

Source: Hill DLG, Hawkes DJ, Crossman JE, Gleeson MJ, Cox TCS, Bracey EECML, et al. (1991)

At one dimension the simple idea of this DWT will be always to reflect the sign for being a superposition wave. Guess a different sign is symbolized with the wavelet decomposition Is Subsequently described as

$$f(t) = \sum_{m,n} c_{m,n} \psi_{m,n}(t) \quad (5.1)$$

Where $\psi_{m,n}(t) = 2^{-m/2} \psi [2^{-m}t - n]$ and m and n are integers.

Wavelet transform for image fusion the schematic diagram for wavelet based fusion techniques is shown in figure 5.2. In the most common methods that the wavelet transforms W of both enrolled input images $I_1(x,y)$ and $I_2(x,y)$ are calculated and also these changes have been united utilizing some type of fusion rule \emptyset . This is given by equation (5.2) below:

$$I(x,y) = w^{-1}(\phi(W(I_1(x,y)), W(I_2(x,y)))) \quad (5.2)$$

where W^{-1} is the inverse discrete wavelet transform (IDWT).

Generally, the basic notion of image mix depending on wavelet change is to implement a multiresolution decomposition on just about every origin picture; the coefficients of this low frequency ring and high-profile rings are then performed with a particular mix rule. Following that, the fused image is accessed by doing the inverse DWT (IDWT) for its corresponding combined wavelet coefficients (Stuart Alexander MacGillivray (2009)).

5.3 Algorithm

Following algorithm has been developed and implemented in MATLAB software.steps:

1. Read the image I1 and find its size.
2. Read the second image I2 and find its size.
3. Compute and match the size if not same, make it same.
4. the indexed image should be DICOM.
5. Perform multilevel wavelet decomposition using any wavelet (haar, db, bior...).
Generate the coefficient matrices of the level-three approximation and horizontal, vertical and diagonal details.
6. Now fuse the wavelet coefficients using discrete wavelet transform.
7. Generate a final matrix of fused wavelet coefficients.
8. Compute the inverse wavelet transform to get the fused image.
9. Finally compute the entropy, SD, PSNR, SNR and display the results

The block diagram for image fusion is shown in figure 5.3

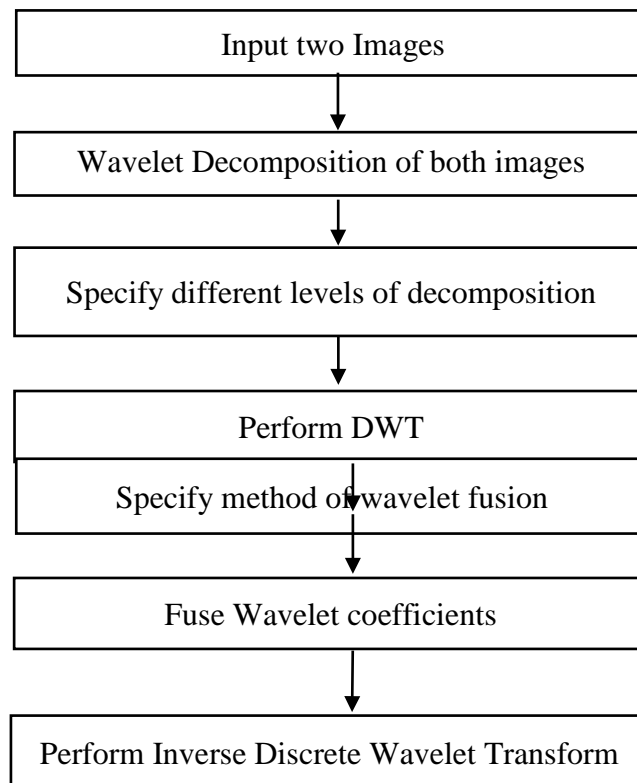


Figure 5.3: Block diagram for image fusion

5.4 Result and Discussion Performance Analysis

The goal of this thesis is to design an algorithm that fuse the medical image in addition to improving the quality of the output image by using wavelet transform. performance of fusion is calculated on the basis of entropy, SD and PSNR.

MRI and CT images are taken as source images (figure 5.5, figure 5.6). MATLAB is used for the simulation. Fusion is performed on source images using different wavelets like db, coif, sym, dmey, bior, rbio and haar. Figure 5.4 represents the fusion of medical images with different wavelet transforms. The MRI & CT medical images (figure 5.5, figure 5.6) are used for the fusion experiment. figure 5.4 (a) & (b) are the source images. The simulations are conducted on such MRI and CT medical pictures for 7 distinct wavelets transform approaches (Bior, coif, db, dmey, haar, rbio and sym). In the entire function the Max- Max wavelet coefficient with level-1 was used.

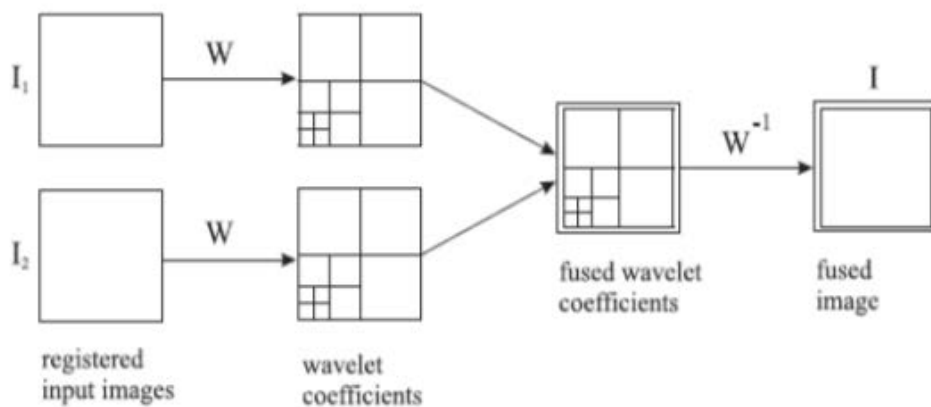


Figure 5.4:Image Fusion using discrete wavelet transform.

Source: J.V.Chapnick, M.E.Noiz, G.Q. Maguire, E.L.Kramer, J.J.Sanger, B.A.Birnbaum, A.J.Megibow,(1993)

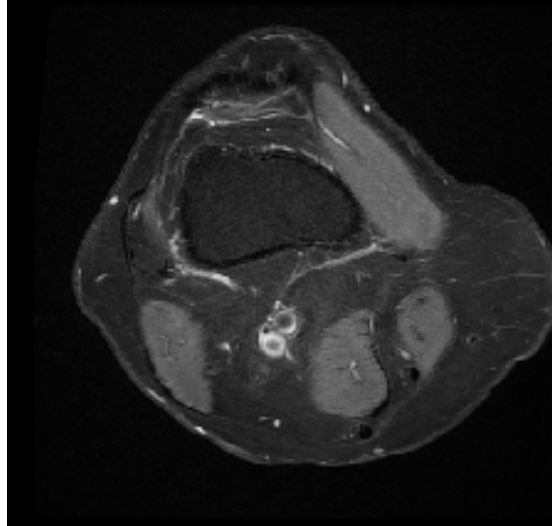


Figure 5.5: MRI image.

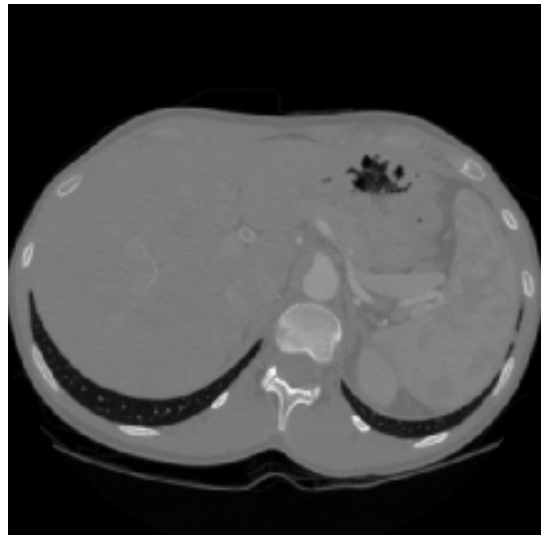


Figure 5.6: CT image.

Source: Url-8

5.4.1 Entropy

Entropy is a parameter to measure the amount of info in the image. Entropy acquaint the info such as numbers in images because of a frequency of modification. When every grey level has the exact same frequency, then the entropy gets the highest value. Quality evaluation is essential as Imaging techniques such as the fusion algorithm can present a few quantities of artifacts or distortion in the signal. For quality evaluation, entropy is employed to appraise the data quantity in image. The greater value of entropy suggests the

revised image is far better than the benchmark image that has more contrast and clarity and is your best image to use for medical purposes. In case entropy of fused image is greater than the source image then it suggests the revised image contains more info than source image and the fused performances are enhanced. Entropy Provides the amount of Data contained in the image, the Further information it Comprises, entropy is defined as:

$$H = -\sum_{i=1}^M \sum_{j=1}^N p_{ij} \log_2 p_{ij} \quad (5.3)$$

$$p_{ij} = \frac{f(i,j)}{\sum_{i=1}^M \sum_{j=1}^N f(i,j)} \quad (5.4)$$

Where H signifies the regional data entropy, p_{ij} is the grey value odds of stage (I, j) from the regional picture, $f(I, j)$ is the grey value of stage (I, j) from the regional picture. The dimensions of the area are $M*N$.

Table 5.1:The Entropy result for merged image

Wavelet	Haar	dmey	Db9	Conif1	Sym3	Bior1.3	Rbio3.1
Entropy	5.7060	5.6236	5.6523	5.6611	5.6857	5.7202	5.7598

The value of this parameter reaches zero when the image does not contain a texture. In addition, it increases when the texture is increased. The entropy value in our proposed work is shown in table 5.1 shown that fused image using biorthogonal wavelets have the highest value compering with other wavelet which mean this result will give us more details than source image.

5.4.2 Standard deviation (sd)

Standard deviation calculates the quantity of grey values which are dispersed in image. In the event of the image fusion, SD measures the comparison of the merge image. High quality of standard deviation is obtained from the absence of noise.

Table 5.2 : The Standard Deviation result for merged image

Wavelet	Haar	dmey	Db9	Conif1	Sym3	Bior1.3	Rbio3.1
SD	0.1423	0.1410	0.1424	0.1419	0.1414	0.1424	0.1431

5.4.3 Peak signal to noise ratio (psnr)

PSNR is your measure of ratio between the highest value of image and the size of the noise present in the image background. Normally PSNR is utilized to assess the reconstruction quality of fused image It suggests that the similarity between two images, the PSNR defined as:

$$PSNR = 10 \frac{\log_{10}(255)^2}{MSE} \text{ dB.} \quad (5.5)$$

$$MSE = \frac{1}{MN} \sum_{i=1}^M \sum_{k=1}^N (x_{j,k} - \tilde{x}_{j,k}) \quad (5.6)$$

MSE is the mean square error signifying the gap between the initial cover picture sized N x N and the stego image sized N x N, along with also the x(j,k) and x'(j,k) are pixel situated in the jth row that the kth column of pictures x and x', respectively. A massive PSNR value usually means the stego image is the most like initial picture and vice versa. It's a challenge for your eyes to differentiate between first cover picture and stego image once the PSNR ratio is significantly bigger than 30dB.

Table 5.3: The Peak Signal to Noise Ratio result for merged image

Wavelet	Haar	dmey	Db9	Conif1	Sym3	Bior1.3	Rbio3.1
PSNR	21.1426	21.2663	21.1470	21.3843	21.2875	21.2949	21.7265

The PSNR value our proposed work is shown in table 5.3 shown that biorthogonal wavelets value is 21.7275 which is the highest result and less than 30dB which mean the human eyes can recognition the different between the resulting images.

5.4.4 Signal-to-noise ratio (snr)

Quantification of this signal-to-noise ratio (SNR) is important in image acquisition processes in electron microscopy and other areas where the image is degraded by noise. Specifically, together with scanning electron microscopy (SEM), the tradeoff with image resolution is usually SNR. The definition of SNR varies based on this area. In electrical engineering and statistical optics, it's defined as the power (variance) ratio between noise and signal, whilst at the electron microscopy that the square root of the amount is usually believed, it is given by

$$SNR = 10 \log_{10} \frac{\sigma_x^2}{\sigma_s^2} \quad (5.7)$$

The SNR value in our proposed work is shown in table 5.4 shown that best result is biorthogonal wavelets compare with another wavelet.

Table 5.4: The Signal-to-noise ratio result for merged image

Wavelet	Haar	dmey	Db9	Conif1	Sym3	Bior1.3	Rbio3.1
SNR	7.9962	8.1435	8.0877	8.2876	8.2626	8.1692	10.2649

In the end we compared our proposed work in term of Entropy, PSNR, SNR from the reference which are in table 5.5. In table 5.5 we can see that from most proposed work is better.

Table 5.5: Comparison of some References with proposed work

Reference No	Entropy	PSNR	SNR	SD
M.D. Nandeesh and Dr.M. Meenakshi (2015),	3.6517	-	-	-
Anna Wang, Haijing Sun, Yueyang Guan, (2006)	2.10596	79.2532	-	-
D.A.Karras, S.A.Karkanis and D.E.Maroulis (2002)	4.8134	CNE: 0.4898	IEN: 4.1696	-
Mr. Yogesh Bute, Prof.V.N.Patil (2014)	-	20.6102	-	-
M.A. Ansari and R.S. Anand (2002)	0.007	15.95	MSE:241	NMI:0.466
The proposed work	5.7598	21.7265	10.2649	0.1431

Where CNE, MSE, NMI, IEN not definition

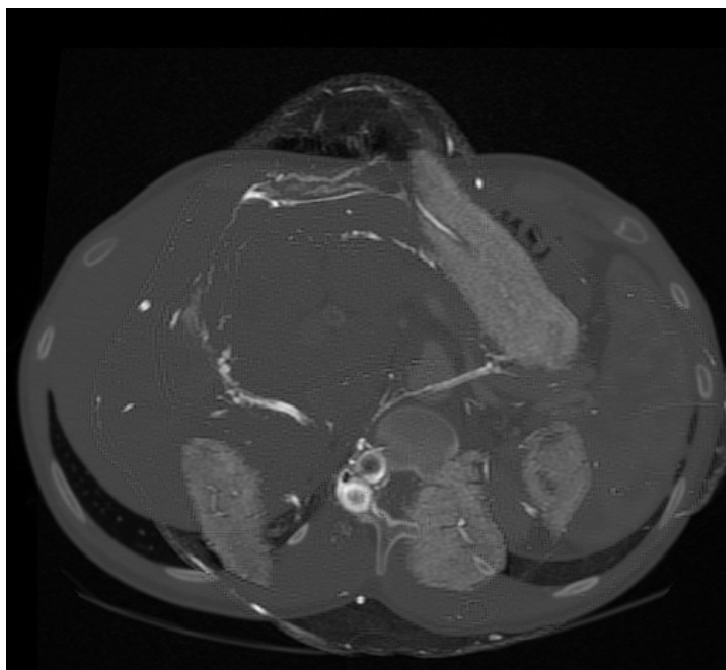


Figure 5.7: the result when we apply Haar Wavelet

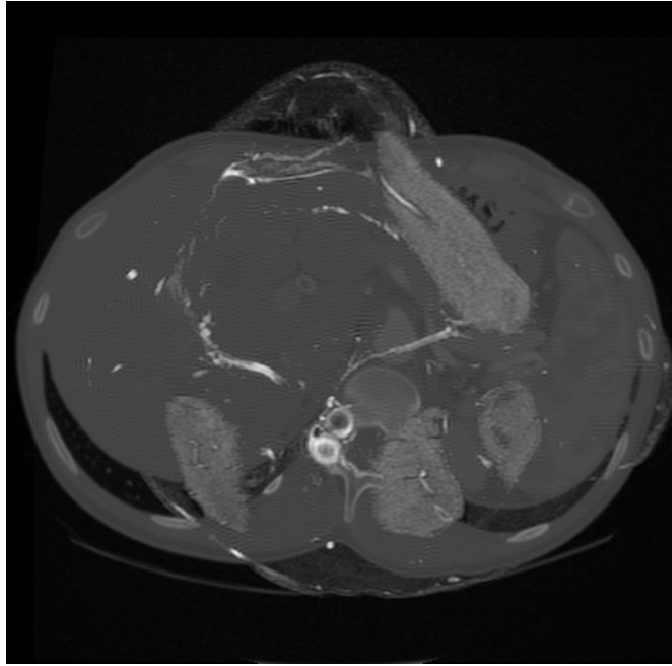


Figure 5.8 : the result when we apply Discrete approximation of Meyer wavelet

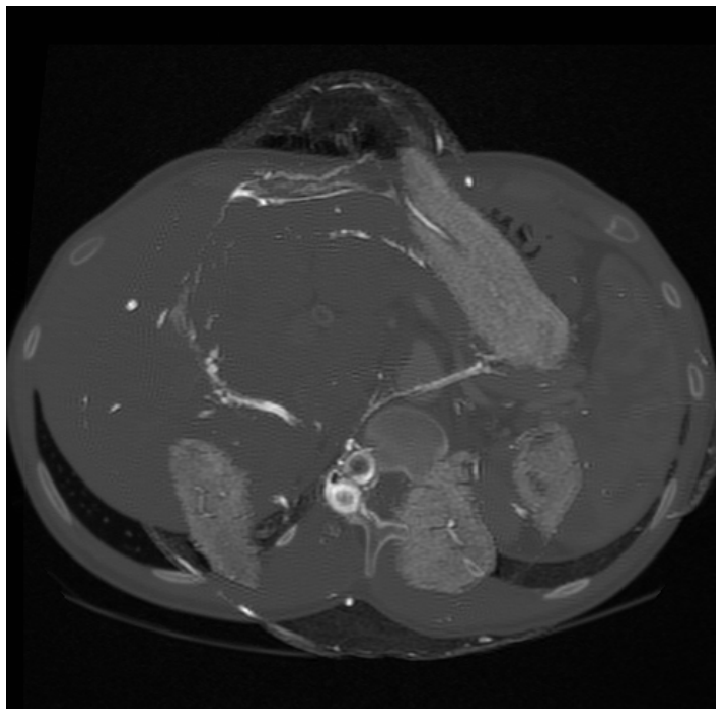


Figure 5.9: the result when we apply Daubechies Wavelets

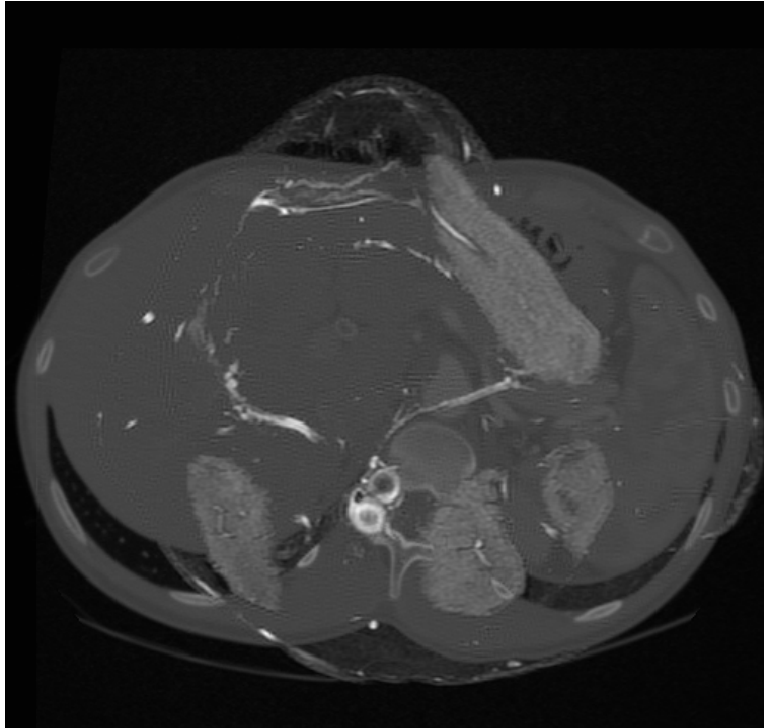


Figure 5. 10: the result when we apply Symlets wavelets

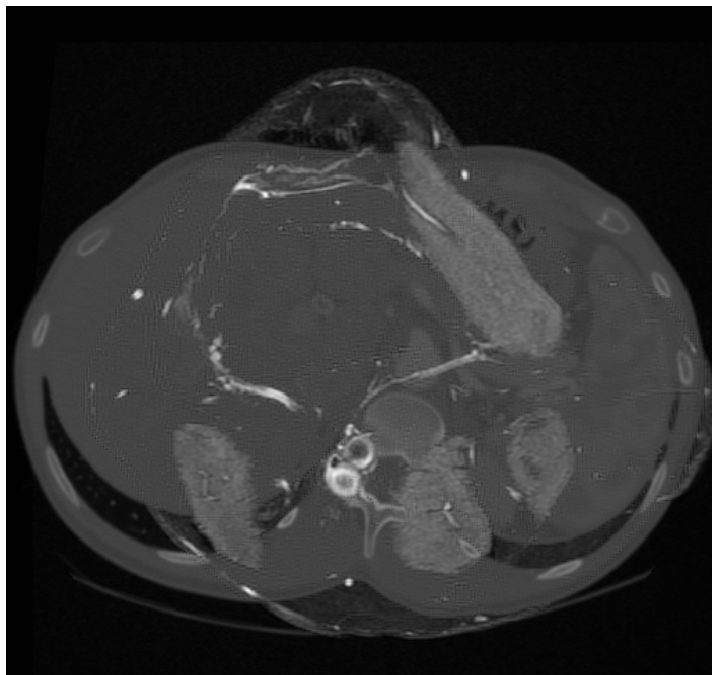


Figure 5. 11: the result when we apply Biorthogonal wavelets

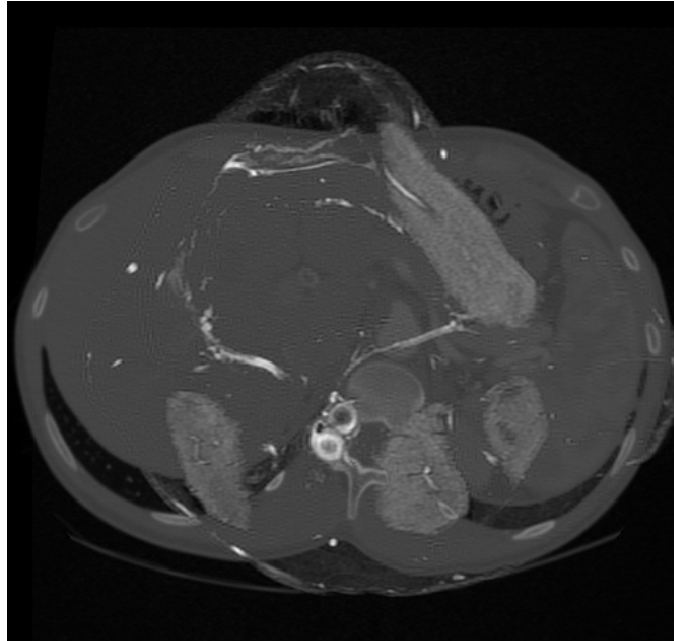


Figure 5.12: the result when we apply Reverse biorthogonal wavelets

5.4.5 Conclusions and future work

In this thesis, the image fusion of MRI & CT medical images is done using fully automated wavelet transforms in MATLAB environment. We used a fusion method like - Bior, coif, db, dmey, haar, rbio and sym. Further, the comparative of image fusion techniques aids in picking out the best result. and so, can provide much better visualization of the fused image. The synthesized image has the qualities of both MRI & CT fused images. After the fusion of the images, it is concluded that the best synthesized image at level 1 with max-max method is Rbio3.1. Using the entropy method as a measuring assessment it is found that the resultant Rbio3.1 image has highest entropy (5.7598), so it is considered as the best fused image having the best quality, clarity and contrast. The worst entropy is obtained for dmey wavelet transforms. The best fused image is distinctively clear, easy to observe and thus, can be analyzed by the doctors for prescribing the proper medication for the shown ailment, in this thesis only (DWT) were investigated in Two-Dimensional. There are more tools like ridgelet transform bandelet transform grouplet transform etc. and we can use that need to be explored for image fusion and also, we can use Three-Dimensional.

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