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Medical Image Fusion Using Wavelet Transform Variants

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Abstract: **Fusion of Medical images derives useful information from medical images containing the data which has important clinical significance for doctors during their analysis. The idea behind the concept of image fusion is to improve the image content by fusing two images like MRI (Magnetic Resonance Imaging) & CT (Computerised Tomography) images to provide useful &precise information for doctor for their clinical treatment. In this paper Discrete Wavelet Transforms (DWT) method has been used to fuse two medical images to decompose the functional & anatomical images. The fused image contains both functional information and more spatial characteristics with no color distortion. In the proposed work different fusion experiments are performed on Medical images by using seven wavelet transform methods - Bior, coif, db, dmey, haar, rbio and sym. Further explores the comparison between all fused image using the measuring parameters Entropy & standard deviation. Experimental results show the best fusion performance is given by theSymlets (sym) wavelet transforms.**

Keywords- **Image Fusion; Frequency; CT; MRI; Entropy; 2-D Discrete Wavelet Transforms Fusion Metrics;**

I. INTRODUCTION

In Image fusion process a fused better visualized image is formed by combining two or more images to retrieve the vital information from these images. Image fusion techniques, merge& integrate the complementary information from multiple image sensor data & makes the image more suitable for the visual perception and processing. Image fusion process extracts all the useful information to minimize redundancy & reduce uncertainty from the source images. Image fusion can combine information from two or more images into a single composite image which become more informative and more suitable for computer processing & visual perception for further analysis and diagnosis. But it is necessary to align two images accurately before they fused .Before fusing images, all features should be preserve in the images and should not introduce any inconsistency or artifacts, so that it could not distract the observer. The advantages of image fusion are improved capability and reliability. The fused image should not have any undesired feature. The idea behind the image fusion concept is that the fused image after image fusion method should possess all relevant information.

The fusion of multi-modality imaging increasingly plays an important role in medical imaging field as the extension of clinical use of various medical imaging systems. Different medical imaging techniques may provide scans with complementary and occasionally redundant information. The fusion of medical images can lead to additional clinical information not apparent in the single images. However, it is difficult to simulate the surgical ability of image fusion when algorithms of image processing are piled up merely. So many solutions to medical diagnostic image fusion have been proposed today. Registered medical MRI and CT images of the same people and same spatial part are used for fusion. The fusion of medical images acquired from different instrument modalities such as MRI (magnetic resonance imaging), CT(computerised tomography), X-rays and PET (positron emission tomography) of the same objects is often needed . A number of fusion techniques have been reported in the literature. The Fusion techniques include different methods for pixel averaging or complicated methods like wavelet transform fusion and principal component analysis. Pixel level image method is comparatively easy to implement & the resultant image contain huge & original information. Many simple image fusion algorithm based on wavelet transform is proposed in reference . The image is decomposed into spatial frequency bands at different scales in wavelet transform method, such as low-low, high-high, high- low and low- high- band. The average image information is given by the low-low band . Other bands High-high, High-low contain directional information due to spatial orientation.

In high bands higher absolute values of wavelet coefficients correspond to salient features such as edges or lines. The common element idea in almost all of them is the use of wavelet transforms to decompose images into a multi resolution scheme . MRI images provide greater contrast of soft tissues of brain than CT images, but the brightness of hard tissues such as bones is higher in CT images. CT &MRI images individually have some Shortcomings such as MRI images not concentrate on hardtissues & in CT image soft tissues can't be clearly visible. In this paper image fusion of CT & MRI images has been carried out so that the fused image which is the combination of soft & hard tissues proven as the focused image for doctors & their clinical treatment. This paper further quantitatively evaluates the fused images quality through two performance measures Standard Deviation (SD) and Entropy (EN).

Wavelet transform

A wavelet is a wave-like oscillation with amplitude that begins at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. Wavelets can be combined, using a "reverse, shift, multiply and integrate" technique called convolution, with portions of a known signal to extract information from the unknown signal.

The word wavelet has been used for decades in digital signal processing and exploration geophysics. The equivalent French word on delette meaning "small wave" was used by Morlet and Grossmann in the early 1980s.

For example, a wavelet could be created to have a frequency of Middle C and a short duration of roughly a 32nd note. If this wavelet was to be convolved with a signal created from the recording of a song, then the resulting signal would be useful for determining when the Middle C note was being played in the song. Mathematically, the wavelet will correlate with the signal if the unknown signal contains information of similar frequency. This concept of correlation is at the core of many practical applications of wavelet theory.

As a mathematical tool, wavelets can be used to extract information from many different kinds of data, including but certainly not limited to audio signals and images. Sets of wavelets are generally needed to analyse data fully. A set of "complementary" wavelets will decompose data without gaps or overlap so that the decomposition process is mathematically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover the original information with minimal loss.

In formal terms, this representation is a wavelet series representation of a square-integrable function with respect to either a complete orthonormal set of basic functions or an over complete set or frame of a vector space, for the Hilbert space of square integrable functions.Wavelet theory is applicable to several subjects. All wavelet transforms may be considered forms of time-frequency representation for continuous-time (analog) signals and so are related to harmonic analysis. Almost all practically useful discrete wavelet transforms use discrete-time filterbanks. These filter banks are called the wavelet and scaling coefficients in wavelets nomenclature. These filterbanks may contain either finite impulse response (FIR) or infinite impulse response (IIR) filters. The wavelets forming a continuous wavelet transform (CWT) are subject to the uncertainty principle of Fourier analysis respective sampling theory. Given a signal with some event in it, one cannot assign simultaneously an exact time and frequency response scale to that event. The product of the uncertainties of time and frequency response scale has a lower bound. Thus, in the scale gram of a continuous wavelet transform of this signal, such an event marks an entire region in the time-scale plane, instead of just one point. Also, discrete wavelet bases may be considered in the context of other forms of the uncertainty principle.

Continuous wavelet transforms

In continuous wavelet transforms, a given signal of finite energy is projected on a continuous family of frequency bands (or similar subspaces of the Lp function space L2(R)). For instance the signal may be represented on every frequency band of the form [f, 2f] for all positive frequencies f > 0. Then, the original signal can be reconstructed by a suitable integration over all the resulting frequency components.

The frequency bands or subspaces (sub-bands) are scaled versions of a subspace at scale 1. This subspace in turn is in most situations generated by the shifts of one generating function ψ in L2(R), the mother wavelet. For the example of the scale one frequency band [1, 2] this function is

$$\psi(t) = 2\,\operatorname{sinc}(2t) - \operatorname{sinc}(t) = \frac{\sin(2\pi t) - \sin(\pi t)}{\pi t}$$

with the (normalized) sinc function. That, Meyer's, and two other examples of mother wavelets are

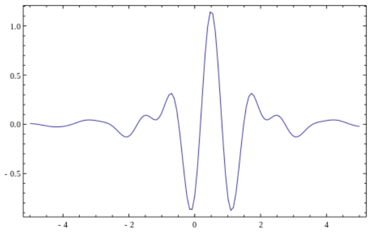


Figure 1: D- Meyer Wavelet.

The subspace of scale a or frequency band [1/a, 2/a] is generated by the functions (sometimes called child wavelets)

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right),$$

where a is positive and defines the scale and b is any real number and defines the shift. The pair (a, b) defines a point in the right half plane R+ × R.

The projection of a function x onto the subspace of scale a then has the form

$$x_a(t) = \int_{\mathbb{R}} WT_\psi\{x\}(a,b) \cdot \psi_{a,b}(t)\, db$$

with wavelet coefficients

$$WT_\psi\{x\}(a,b) = \langle x, \psi_{a,b} \rangle = \int_{\mathbb{R}} x(t)\psi_{a,b}(t)\, dt.$$

See a list of some Continuous wavelets.

For the analysis of the signal x, one can assemble the wavelet coefficients into a scaleogram of the signal.

Discrete wavelet transforms

It is computationally impossible to analyze a signal using all wavelet coefficients, so one may wonder if it is sufficient to pick a discrete subset of the upper halfplane to be able to reconstruct a signal from the corresponding wavelet coefficients. One such system is the affine system for some real parameters a > 1, b > 0. The corresponding discrete subset of the halfplane consists of all the points (am, namb) with m, n in Z. The corresponding baby wavelets are now given as

$$\psi_{m,n}(t) = a^{-m/2}\psi(a^{-m}t - nb).$$

A sufficient condition for the reconstruction of any signal x of finite energy by the formula

$$x(t) = \sum_{m\in\mathbb{Z}} \sum_{n\in\mathbb{Z}} \langle x,\, \psi_{m,n} \rangle \cdot \psi_{m,n}(t)$$

is that the functions $\{\psi_{m,n} : m, n \in \mathbb{Z}\}$ form a tight frame of L2(R).

In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency and location information (location in time).

Haar wavelet

The first DWT was invented by the Hungarian mathematician Alfréd Haar. For an input represented by a list of 2^n numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally resulting in 2^n-1 differences and one final sum.

Daubechies wavelets

The most commonly used set of discrete wavelet transforms was formulated by the Belgian mathematician Ingrid Daubechies in 1988. This formulation is based on the use of recurrence relations to generate progressively finer discrete samplings of an implicit mother wavelet function; each resolution is twice that of the previous scale. Daubechies derives a family of wavelets, the first of which is the Haar wavelet. Interest in this field has exploded since then, and many variations of Daubechies' original wavelets were developed.

The Dual-Tree Complex Wavelet Transform (WT)

The Dual-Tree Complex Wavelet Transform (WT) is a relatively recent enhancement to the discrete wavelet transform (DWT), with important additional properties: It is nearly shift invariant and directionally selective in two and higher dimensions. It achieves this with a redundancy factor of only 2^d substantially lower than the undecimated DWT. The multidimensional (M-D) dual-tree WT is nonseparable but is based on a computationally efficient, separable filter bank (FB).

The discrete wavelet transform has a huge number of applications in science, engineering, mathematics and computer science. Most notably, it is used for signal coding, to represent a discrete signal in a more redundant form, often as a preconditioning for data compression. Practical applications can also be found in signal processing of accelerations for gait analysis,in digital communications and many others.

It is shown that discrete wavelet transform (discrete in scale and shift, and continuous in time) is successfully implemented as analog filter bank in biomedical signal processing for design of low-power pacemakers and also in ultra-wideband (UWB) wireless communications.

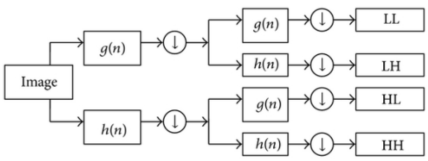


Figure 2 : 2D 4 Band Filter bank DWT.

II. IMAGE FUSION BASED ON DIFFERENTWAVELET TRANSFORMS

The original concept and theory of wavelet-based multi-resolution analysis gave by mallat. Wave let transform has increasingly important in image fusion since wavelet allows both time & frequency analysis simultaneously. The wavelet transform is nothing but a mathematical tool. It can detect local features in a signal process and also can be used for multi-resolution analysis to decompose two-dimension (2-D) signal such as 2-D grey scale image signals into different resolution levels. Wavelet transform widely used for many fields, such as data compression, feature detection, texture analysis, image fusion, and many more. In image fusion method, the formation of fusion pyramid is the most important step. The basic idea of image fusion based on wavelet transforms which perform a multi-resolution decomposition of each source image and the coefficients of both the low frequency band and high frequency bands are then performed with certain fusion rule. At first compute the wavelet transforms of images, then decompose the image into various sub images based on local frequency content and by choosing the salient wavelet coefficients; a composite multi-scale representation is built. The common integration rule is that the coefficients whose absolute values are higher being selected at every point in the transform domain. The larger absolute wavelet transform coefficients correspond to sharper brightness changes. In this way the fusion takes place in all the resolution levels and the more dominant features at each scale are preserved in the new multi-resolution representation. A new image has been constructed with the help of specific rules of decision or weighting by performing an inverse wavelet transformation. In wavelet transformation, at each level of decomposition process, the image size is halved which lead to a multi-resolution signal representation, in both spatial directions.

Different types of wavelet methods has been used in image fusion process such as Biorsplines (bior), coiflets (coif), daubechies (db), dmeyer (dmey), Haar (haar), reverse bior (rbio) and symlets (sym). Daubechies wavelets are the most popular wavelets among all of them.Daubechies wavelet used in many applications &are supposed to be the foundations of wavelet signal processing. Coiflets, Haar, Symlets and Daubechies, are capable of perfect reconstruction &compactly supported orthogonal wavelets. The Mexican Hat,Morlet and Meyer wavelets are symmetric in shape. Bi orthogonal wavelet exhibits the property of linear phase & needed for image reconstruction and signal processing. These wavelets are chosen in a particular application based on their ability and their shape to analyse the signal wavelets. Wavelet transforms has two groups i.e. DWT (discrete wavelet transforms) & CWT (continuous wavelet transforms).DWT has the features of fast operational speed and occupies less memory & also maintains the characteristics of wavelet. The continuous function transforms into a highly redundant function of two continuous variables; translation & scale in CWT. In this paper, image fusion process is carried out in MATLAB using DWT method. The concept and procedure of the wavelet based fusion technique has been presented in below figure.

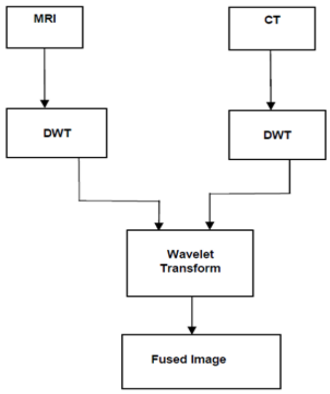


Figure 3 : Image Fusion Block Diagram.

III. PERFORMANCE ASSESSMENT.

Although wavelets share some common properties, yet fusion results varies because of their unique image reconstruction and decompression characteristics. The general requirement is to preserve all valid and useful pattern information from the source images and also it should introduce artifacts that could interfere with subsequent analyses simultaneously. The performance measures used in this paper are SD (Standard Deviation) & EN (entropy). It provides quantitative comparison among different fusion schemes. It focuses mainly at measuring the definition of an image.

Standard Deviation (SD)

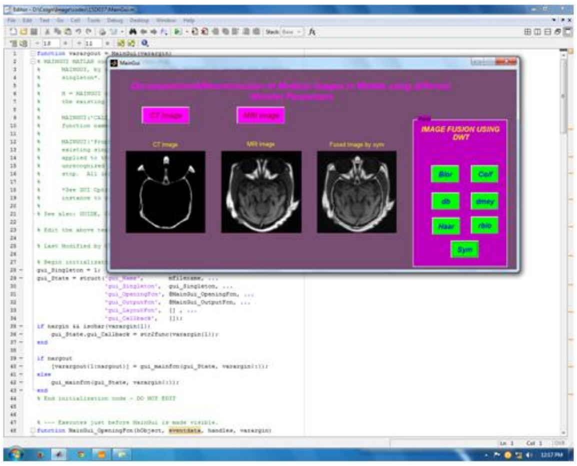
The standard deviation (SD) is the among the most commonly used assessment measure of statistical dispersion, SD evaluate how widely spread the gray values in an image and measures the fused image contrast. SD denotes the deviation degree of the estimation and the average of the random variable. SD produces best results in the absence of noise. An image with high contrast would have a high standard deviation. For better results SD should be at the higher end. Larger the standard deviation, better the result.The unbiased estimate of the standard deviation, Sa of the brightness within a region (Ř) with pixels is called theSample standard deviation.

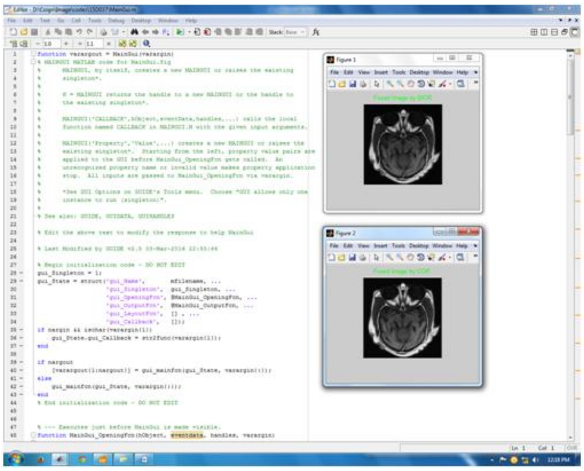
Entropy (EN)

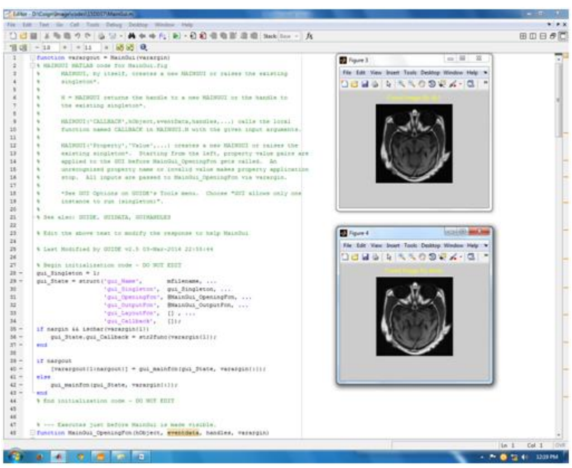
Shannon was the first person to introduce entropy to quantify the information. Entropy is a quantitative measure. Entropy defined as the amount of information contained in a signal. The concept of EN has been employed in many scientific fields as well as in image processing methods and it contains the information content of an image. Entropy is an parameter to evaluate the information quantity contained in an image. Entropy defines the information in the digital numbers in images as a frequency of change. Entropy reflects an average information content of an image.When each gray level has the same frequency, then the Entropy has the maximum value. If entropy of fused image is higher than the source Image then it indicates that the fused image contains more information than source image and the fusion performances are improved.

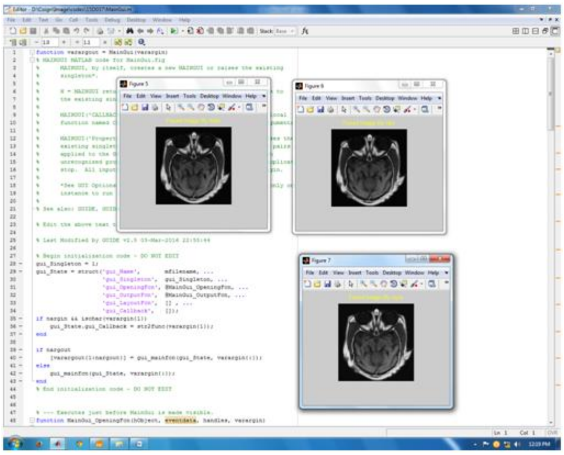
IV. EXPERIMENTAL RESULTS

The MRI & CT medical images are used in this fusion experiment. The simulations are performed on these CT scan and MRI Medical images for different wavelet transform methods (Bior, coif, db, dmey, haar, rbio and sym) .









V. CONCLUSION

In this paper, the image fusion of MRI & CT medical images is done using fully automated wavelet transforms in MATLAB environment. The synthesized image has the qualities of both MRI & CT fused images. The different fusion methods used are - Bior, coif, db, dmey, haar, rbio and sym. Further the comparative analysis of a number of image fusion techniques helps in selecting the best fusion method and therefore one can obtain better visualization of the fused image. The worst entropy & Standard Deviation are obtained for Dmeyer (dmey) & Coiflets (coif) wavelet transforms respectively. The Symlets (sym) wavelet transform gives best Entropy & Standard Deviation .Thus the Symlets (sym) fusion method with LR Fusion – Max wavelet coefficients outperforms other fusion methods.

VI. REFERENCES

[1] Malviya, A. and Bhirud S. G, “Image Fusion of Digital Images”, International Journal of Recent Trends in Engineering, vol.2, no.3 , 2009.

[2] Irshad, H., Kamran, M., Siddiqui, A.B. and Hussain, A., “Image fusion using computational intelligence: A survey”, 2nd International conference on Environmental and Computer Science, IEEE Computer Society, pp. 128-132, 2009.

[3] The Image fusion website [Online]: http:// www. Image fusion .org.

[4] MA Yong-guang, LI Zhi-xin, “A New Arithmetic for Image Fusion Based on Fuzzy Wavelet Transform”, Second International Conference on Information and Computing Science, pp.365-368, 2009.

[5] Yi. Zhou, “Principal component analyses based image fusion routine with application to stemping split detection, a Dissertation”, presented to the graduate school of Clemsen university, 2010.

[6] Maruturi Haribabu,CH.Hima Bindu and.K.Satya Prasad, "Multimodal Medical Image Fusion of MRI – PETusing Wavelet", International Conference on Advances in Mobile Network, Communication and Its Applications, 2012.

[7] Kirankumar Y., and Shenbaga Devi S, "Transform- based medical image fusion", Int J. Biomedical Engineering and Technology, vol. 1, no.1, 2007.

[8] Changtao He, Quanxi Liu, Hongliang Li and Haixu Wange,"Multimodal medical image fusion based on IHS & PCA", Procedia Engineering vol. 7, 2010, pp 280-285.

[9] Xiaoqing Zhang; Yongguo Zheng; Yanjun Peng; Weike Liu and Changqiang Yang, "Research on Multi-Mode Medical Image Fusion Algorithm Based on Wavelet Transform and the Edge Characteristics of Images," pp. 1-4, 2009.

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