# Multimodal Image Fusion Techniques for Medical Images using Wavelets

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**Abstract-** Image fusion has become crucial part of medical diagnosis. This paper gives introduction to image fusion methods based on wavelet transform. Fusion of CT scanned images and MRI images using multi resolution wavelet transform with necessary preprocessing of it is proposed. It also compares the performance of the various types of wavelet basis families used and the different fusion rules used to fuse the approximation and detail wavelet coefficients.

**Index Terms-** Image Fusion, Discrete Wavelet Transforms, CT, MRI, multimodal medical Image fusion, Medical imaging, Fusion performance metrics, entropy, Mean Square Error, Peak Signal to Noise Ratio

## 1. INTRODUCTION:

The process of combining the relevant information from a set of images into a single superior quality fused image is called as image fusion. This high quality fused image needs to have better spatial and spectral information, than any of the input images [4][2].

Image fusion method can be broadly classified into two groups [5] –

1. Spatial domain fusion method
2. Transform domain fusion.

In spatial domain techniques, the pixel values are manipulated to achieve desired result. The Spatial domain fusion methods include averaging, Brovey method, principal component analysis (PCA), Intensity Hue saturation (HIS) based methods and high pass filtering based technique. The spatial domain approaches is that tend to produce spatial distortion and Spectral distortion in the fused image, hence prove a disadvantage. In transform domain methods the image is first transferred into another domain, say frequency domain and all the fusion operations are performed on the transform of the image and then the inverse transform is performed to get the resultant image. Spatial distortion can be very well handled by frequency domain approaches on image fusion. However, its excellent characteristic in one-dimension can't be extended to two dimensions or multi-dimension simply. The multi resolution analysis has become a very useful tool for analyzing remote sensing images, medical images etc. The discrete wavelet transform is now becoming a very important tool for fusion.

Image Fusion techniques play important role in medical imaging, microscopic imaging, remote sensing, computer vision and robotics. In medical field, the different modalities like X-rays, CT scan, MRI Scan, nuclear medicine and other modalities are used to examine the organs of body have their own advantages and disadvantages. Major advantage of the CT is its ability to image bone and blood vessels all at the same time. In the CT scanned image of the brain hard tissue like the skull bone is clearly seen but the soft tissue like the membranes covering the brain are less visible and hence CT is not sensitive in detecting inflammation of the membranes in the brain. In the MRI scanned image of the same brain we observe the soft tissue like the membranes covering the brain can be clearly seen but the hard tissue like the skull bones cannot be clearly seen. [10] These are the demerits of the CT and MRI scans. Combination of CT and MRI scanned images of the brain then yields an image in which both hard tissue like skull bones and the soft tissue like the membranes covering the brain can be clearly visible. The main purpose of medical image fusion is to obtain a high resolution image which contains as much details as possible for the sake of diagnosis. So if these two images of the same organ are fused then the fused image contains considerably more amount of information for diagnosis of that organ, as compared to the non-fused images.

## 2. DISCRETE WAVELET TRANSFORMS

Wavelets are finite duration oscillatory functions with zero average value. They have finite energy and hence are suited for analysis of transient signal. [4] Wavelets can be described by using two functions namely the scaling function f(t) or father wavelet and the wavelet function ψ(t) or mother wavelet.[7][8]

A number of basis functions can be used as the mother wavelet for Wavelet Transformation. The mother wavelet through translation and scaling produces various wavelet families which are used in the transformation. The wavelet families are given by following equation numbered 1,

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right), (a, b \in R), a > 0 \ldots\ldots \quad (1)$$

The Haar, Daubechies, Symlets and Coiflets are compactly supported orthogonal wavelets. These wavelets along with Meyer wavelets are capable of perfect reconstruction. The Meyer, Morlet and Mexican Hat wavelets are symmetric in shape. The wavelets are chosen based on their shape and their ability to analyze the signal in a particular application.

The Discrete Wavelet Transform has the property that the spatial resolution is small in low-frequency bands but large in high-frequency bands. This is because the scaling function is treated as a low pass filter and the mother wavelet as high pass filter in DWT implementation. [4]

The wavelet transform decomposes the image into low-high, high-low, high-high spatial frequency bands at different scales and the low-low band at the coarsest scale which is shown in figure 1(a). The low-low image has the smallest spatial resolution and represents the approximation information of the original image. The other sub-images, on the contrary show the detailed information of the original image.

There are different levels of decomposition which are shown in Figure 1. After one level of decomposition, there will be four frequency bands, as listed above. The next level decomposition is just applied to the LL band of the current decomposition stage, which forms a recursive decomposition procedure. Thus, N-level decomposition will finally have 3N+1 different frequency bands, which include 3N high frequency bands and just one LL frequency band. [12]

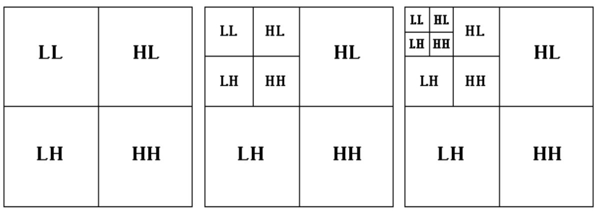


Fig. 1. Wavelet Transform (a) Single Level decomposition (b) Two level decomposition (c) three level decomposition

## 3. IMAGE FUSION USING DWT

### 3.1 *Preprocessing for Image Fusion*

The multimodal images which are needed to be fused need to be processed prior to application of fusion algorithm. [8] The pre-processing includes image registration, image resizing and histogram equalization.

3.1.1. *Image Registration*

The images which are obtained by different modalities might be of different orientations and hence are needed to be registered before they are fused.

3.1.2. *Image Resizing*

Also the sizes of the images might vary so before fusion, the images are needed to be resized so that both the images are of the same size. This is done by interpolating the smaller size image by rows and columns duplication.

3.1.3 *Image Enhancement*

If both or any of the images are not of grayscale then it is desired that it is converted to grayscale. The next step which follows this is equalization of the histograms of the images so that the contrast of the image is enhanced and that both the images have similar range of values for wavelet coefficients.

### 3.2 *Image Fusion Algorithm*

The steps in the algorithm for image fusion using DWT as shown in Figure 2 are as follows:

(1) Read the input images (MRI & CT Scanned).
(2) Resample and register both these images.
(3) Apply 2D-discrete wavelet transform to these images which decompose it into four sub-bands (LL, LH, HL and HH).
(4) The Wavelet coefficients obtained from both the images are fused using the rules for fusion.
(5) The final fused image is reconstructed by applying inverse discrete wavelet transform to fused image.

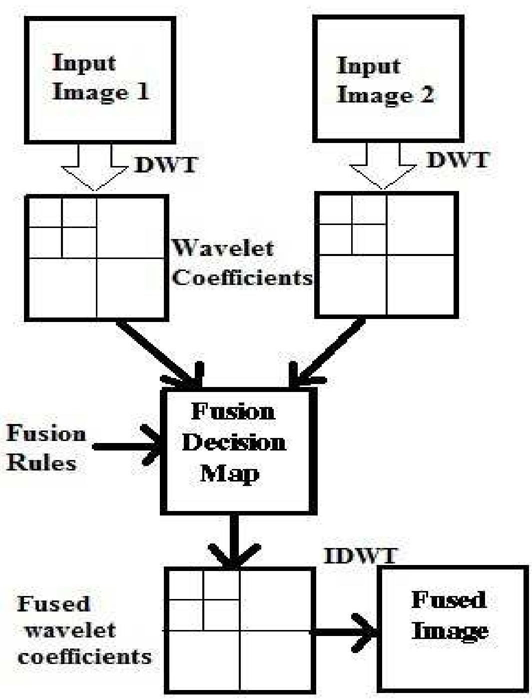


Fig. 2. Block diagram of Image Fusion process using DWT

### 3.3 *Fusion Rules*

By application of Wavelet Transforms to the images we obtain the Wavelet Coefficients which are called as approximation coefficients, horizontal detail coefficients, vertical detail & diagonal detail coefficients. [6]These corresponding coefficients of each of the image are to be fused together in a particular manner.

Certain rules that can be used for the same are Maximum value, Minimum value, Mean Value and Random value. These techniques respectively merge the two approximations or details structures obtained from the images to be fused, element wise by taking the maximum, minimum, mean or a randomly chosen element. Besides these there are other rules of fusing the wavelet coefficients such as linear fusion rule, Up-down fusion rule, down-up fusion rule, left-right fusion rule and right-left fusion rule.

## 4. PERFORMANCE METRICS TO EVALUATE IMAGE FUSION TECHNIQUES:

The image fusion process should preserve all valid and useful information from the input images, so also it should not introduce undesired artifacts. Various metrics are used in order to evaluate the performance of Image Fusion techniques. [4] They are as follows:

### 4.1. *Entropy:*

Entropy measures the information quantity contained in an image. [7][11] Higher entropy value of the fused image indicates presence of more information and improvement in fused image. If L is the total of grey levels and p= $\{p_0, p_1, \ldots, p_{L-1}\}$ is the probability distribution of each level, Entropy is defined as,

$$E = \sum_{i=0}^{L-1} p_i \log(p_i) \qquad (2)$$

### 4.2. *Mean Square Error:*

The MSE between image X, and an approximation, Y, is the squared norm of the difference divided by the number of elements in the image. If i and j are pixel row column indices, M and N are the number of rows and columns, MSE is defined by,

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(X_{ij}-Y_{ij})^2 \qquad (3)$$

### 4.3.*Peak Signal to Noise Ratio:*

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of the signal. It is defined by,

$$PSNR = 20\log_{10}\left(\frac{2^B-1}{\sqrt{MSE}}\right) \qquad (4)$$

## 5. RESULTS:

The image fusion was carried over for multimodal images obtained from CT and MRI scans. The wavelet used was second order symlet and different types of fusion rules were used for the same set of images. After obtaining the synthesized image the performance evaluation of the images was carried out.


Fig. 4.a CT scan image

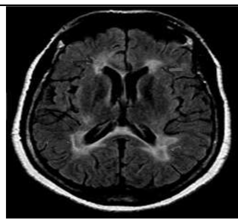
Fig. 4.b MRI Scan Image

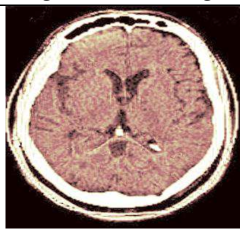
Fig. 4.c Max-Max Fused image

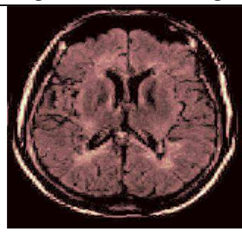
Fig. 4.d Min-Min Fused Image

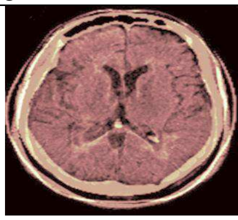
Fig. 4.e. Mean-Mean Fused image

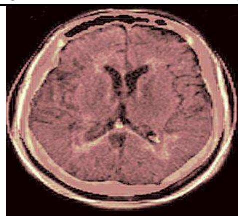
Fig. 4.f. Lin-Lin Fused image

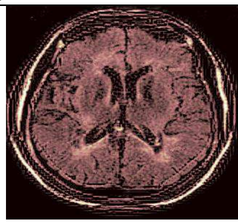
Fig. 4. g Min-Max Fused image

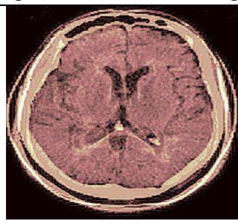
Fig.4.h. Lin-Max Fused image

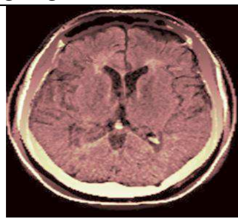
Fig. 4.i. Down_Up-Down_Up Fused image

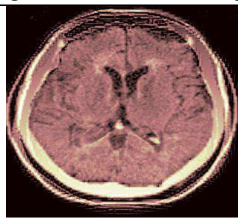
Fig. 4.j. Down_Up-Up_Down Fused image

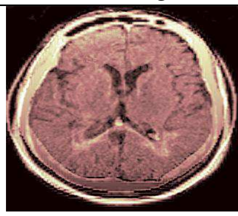
Fig. 4.k Up_Down Down_Up Fused image

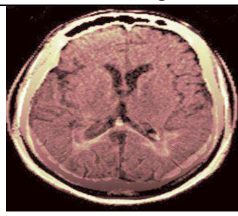
Fig. 4.l Up_Down- Up_Down Fused image

The synthesized images are shown in Figure 4. The figures 4.a, b show the input CT scanned image and MRI scanned image respectively.

Fig. 4.c,d,e,f show synthesized image having fused the both approximation and detail coefficients using maximum fusion rule, minimum fusion rule, mean fusion rule, linear fusion rule respectively. Whereas Figures 4.g,h, show image fused by using minimum and linear fusion rule for approximation coefficients respectively and maximum fusion rule for detail coefficients. Figure 4. i,j,k,l show combinations of up_down and down_up fusion rules.

The results obtained for entropy are displayed in the table 1.

Table 1 Image Fusion rules and corresponding Entropy.

| **Fusion Rule** | **Entropy (bits)** |
|---|---|
| Original CT Scanned image | 6.3070 |
| Original MRI Scanned image | 5.6294 |
| Max-Max Fused image | 7.1072 |
| Min-Min Fused Image | 6.4442 |
| Mean-Mean Fused image | 6.9795 |
| Linear-Linear Fused image | 6.9849 |
| Min-Max Fused image | 6.6570 |
| Lin-Max Fused image | 7.0746 |
| Down_Up-Down_Up Fused image | 7.0227 |
| Down_Up-Up_Down Fused image | 7.0378 |
| Up_Down Down_Up Fused image | 7.0378 |
| Up_Down- Up_Down Fused image | 7.1133 |

## *6.* CONCLUSION:

The synthesized image has the merits of both CT & MRI scanned images. In this paper, the comparison of various fusion rules to fuse wavelet coefficients in the image fusion process is carried out. In this paper, 10 kinds of wavelet-based fusion methods are compared. The Entropy (EN) has been used as image fusion evaluation criterion for quantitative analysis of image fusion results. The Matlab fusion results indicate that the fusion methods produced higher entropy, the highest being produced by Up_Down- Up_Down technique. The comparative analysis of image fusion techniques allows in selecting the best fusion method and therefore one can obtain better visualization of the fused image.

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