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# Wavelet based Analysis of Medical Image Fusion using MATLAB GUI

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**ABSTRACT:** Medical image fusion is the technique which combines two or more medical images into a single image, which contains the information of both the recorded medical images. This method is mainly used in diagnosis. Normally images like MRI and CT are used as source images. Discrete Wavelet Transform is used for the medical image fusion execution. In this paper, different fusion methods are performed on medical images using wavelets like db, coif, sym, dmey, bior, rbio and haar. These fusion methods are analyzed using different performance parameters like entropy, standard deviation, PSNR, NAE, RMSE to select the better method.

**KEYWORDS:** Image fusion, DWT, PSNR, NAE, RMSE, IDWT, CT, MRI, Entropy, Fusion rules, GUI.

## I. INTRODUCTION

Image fusion is the technique in which the information from multiple images is combined into a single image, which includes the information corresponding to the multiple images [1]. Thus obtained image should contain more information than the original images. Image fusion technique reduces the redundancy and uncertainty by extracting the useful information from the source image [2]. Before image fusion, the proper alignment of the images should be done in order to obtain the better visualized fused image [3]. In case of Medical image fusion technique, we can combine two or more medical images into single image, which contains the information corresponding to both the recorded medical images. This method is used mainly in diagnosis. Generally images like MRI and CT are used for this purpose, which provides helpful information for doctors in their treatment. Different types of fusion techniques are explained in literature [4-5]. Fusion based on wavelet transform is used in the proposed work which is the pixel level image fusion technique. Normally wavelet transforms decomposes the image into high frequency band and low frequency band at different level such as low-low, high-low, low-high, high-high bands. Low frequency bands which provides duplicate image of the original image and all the information corresponding to the original image is included in this band which is known as approximate coefficients. High frequency bands provide edge and outline information of the source image in the fused image and it also determines the luminance change with reference to the edge information which is known as detailed coefficients. This paper further quantitatively analyse the fused image quality by using performance parameters like entropy, standard deviation, PSNR, NAE and RMSE.

The organization of the paper is as follows: section II explains the different wavelet transforms used in fusion of images. Section III highlights the different performance parameter used in fusion method for the quantitative analysis. Section IV elaborates the presentation and discussion of experimental result. Section V details the overall conclusion of the proposed paper.

## II. WAVELET BASED IMAGE FUSION

The wavelet analysis concept is originally proposed by Mallat. Because of simultaneous analysis of both time and frequency, wavelets are used in image processing applications. The main advantage of the wavelet transform is that it can decompose the normal two dimensional images into multi resolution levels. Wavelet transforms are widely used in image fusion, edge detection, texture analysis and data compression. The basic concept of wavelet based image fusion is to perform the multi resolution decomposition of the individual source images and the decomposed image coefficients

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are combined using fusion rules. Generally coefficients with higher absolute value is selected which provides sharper brightness in the fused image. The fusion is combination of both the approximate coefficients and details coefficients in the source image. In the each decomposition levels, the image size is to be halved so that the multi resolution arrangements are established in both the spatial direction. Daubechies, Coiflets, Symlets, Discrete Meyer, Biorthogonal, Reverse Biorthogonal and Haar are the different types of wavelets used in the fusion process.

### Haar

Haar wavelets are also known as rescaled sequence of “square-shaped” function which is one of the oldest and simplest wavelets. Since it is not continuous in nature, it cannot be differentiable. Wavelet function  $\varphi(t)$  and scaling function  $\phi(t)$  of the Haar wavelet is represented as:

$$\varphi(t) = \begin{cases} 1 & 0 \leq t < \frac{1}{2} \\ -1 & \frac{1}{2} \leq t < 1 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

$$\phi(t) = \begin{cases} 1 & 0 \leq t < 1 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

### Daubechies

It is orthogonal wavelets which produce the maximum number of vanishing moments. It supports both continuous as well as discrete transforms. In these wavelets, scaling function generates the orthogonal multiresolution.

### Coiflets

Coiflets wavelets are discrete in nature which contains the scaling function with number of vanishing moments. This wavelet having  $\frac{N}{3}$  number of vanishing moments in wavelet function and  $\frac{N}{3} - 1$  vanishing moments in scaling function.

Both wavelets as well as scaling function are normalized by factor  $\frac{1}{\sqrt{2}}$ .

### Symlets

In symlet wavelets both the scaling and wavelet functions are compactly supported. It is one of the most commonly used orthogonal wavelet. Poor regularity is the only concern in case of Symlets.

### Discrete Meyer

It is a FIR approximation of the meyer wavelet. Both the continuous and discrete wavelet transforms are supported in this wavelets.

### Biorthogonal and Reverse Biorthogonal

In this type of wavelets, wavelet transform is invertible but wavelet need not be orthogonal. Construction of the symmetric wavelet function is possible by this method. Normally two wavelet and scaling function is present in this wavelet to produce the perfect reconstruction.

Based on the user application as well as type of reconstruction needed, these wavelets are selected in the analysis of the image fusion process. After the decomposition, the fusion rules combine the both approximation and details coefficients into fusion coefficients. By using the Inverse Discrete Wavelet Transform (IDWT), fusion coefficients are converted into fused image. Figure 1 represents the simple method of image fusion based on different wavelet transforms. The medical image fusion can be analyzed by the graphical user Interface in MATLAB 2013a. A suitable MATLAB code has been written in graphical user interface to fuse these medical images with reference to the various different types of wavelet transforms and various decomposition levels. A choice of wavelets has been given to the user. Different wavelets like db, coif, bior, sym, rbio, dmey, haar can be selected for the fusion with different decomposition levels. User has different options for fusion method both for approximation coefficients and detail coefficients i.e., maximum, minimum, mean, Image 1, Image 2, and random which merges the two approximations or detail structures obtained from Image 1 and 2 element wise. The Graphical User Interface (GUI) model for the medical image fusion is shown in Figure 2.

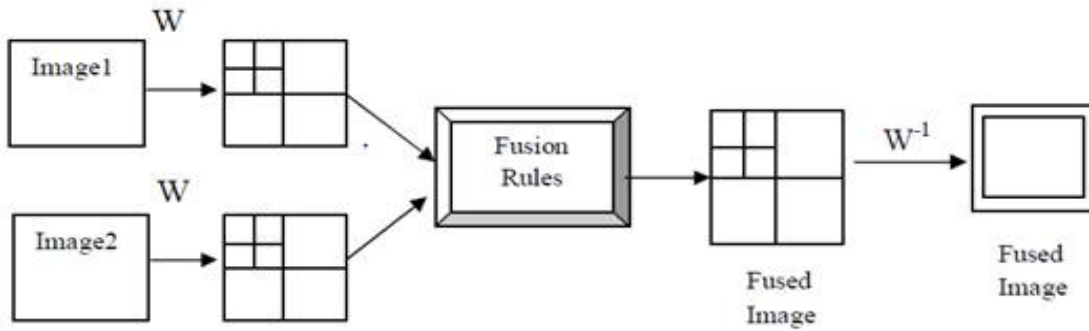


Figure 1: Image Fusion based on Wavelet Transforms [5]

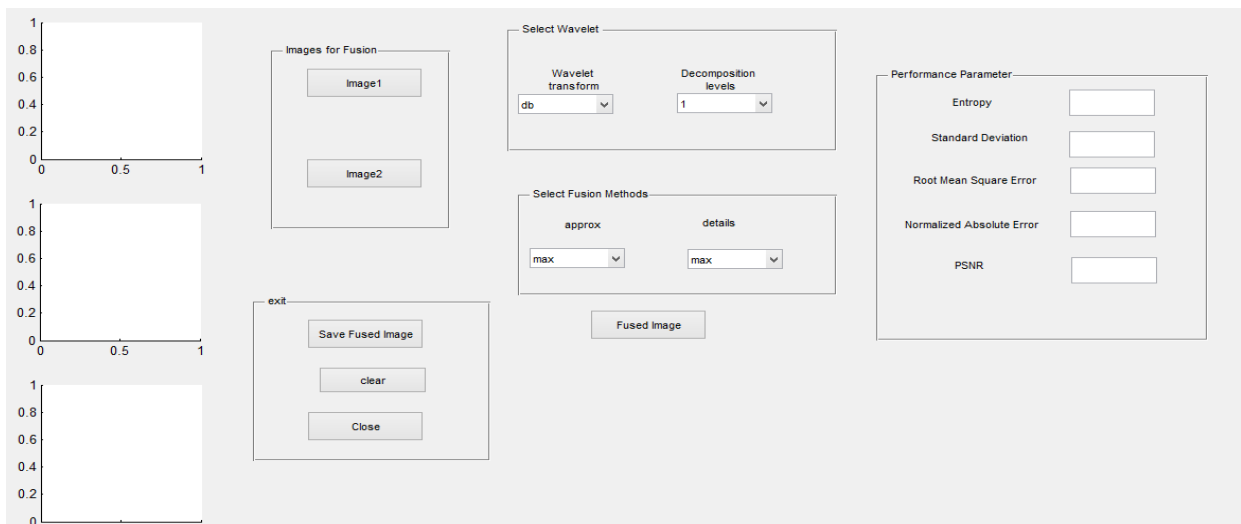


Figure 2: MATLAB GUI Model for Fusion of Medical Images

### III.PERFORMANCE ANALYSIS

Even though wavelets sharing same properties in nature, the fusion result are different. This is because of their uniqueness in image decomposition as well as the image reconstruction characteristics. Entropy, RMSE, NAE, standard deviation and PSNR are used in this paper for the quantitative analysis of the fused image.

#### Entropy (H)

Entropy indicates the amount of information contents present in the image. If the entropy is higher in the fused image then it indicates that fused image carrying greater information compare to the source image. The larger the value of entropy, better the fusion results.

#### Root Mean Square Error (RMSE)

RMSE presents the amount of deviation present in the fused image compared to source image. RMSE value should as low as possible for the better quality image.

#### Peak Signal to Noise Ratio (PSNR)

PSNR is the measure of ratio between the maximum value of an image and the magnitude of the noise present in the image background. Normally PSNR is used to measure the reconstruction quality of fused image. It indicates the similarity between two images. The higher PSNR value gives the better fused image.

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### Normalized Absolute Error (NAE)

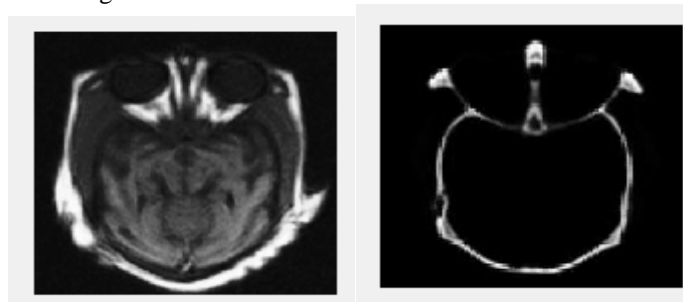
NAE measures the amount difference in position of the fused image compare to the original source image. The higher value of NAE indicates poor quality of the image.

### Standard Deviation (SD)

Standard deviation calculates the amount of gray values that are spread in an image. In case of the image fusion, standard deviation measures the contrast of the fused image. High value of standard deviation is obtained in the absence of noise.

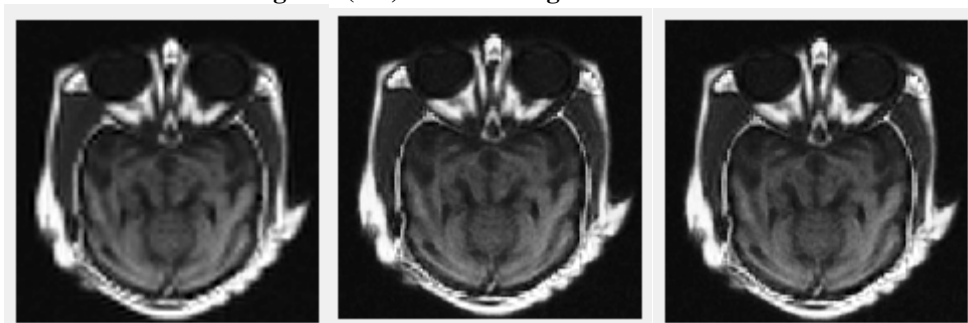
## IV. RESULTS

In this paper, MRI and CT images are taken as source images (Figure 3). MATLAB GUI tool is used for the simulation. Fusion is performed on source images using different wavelets like db, coif, sym, dmey, bior, rbio and haar. Figure 4 represents the fusion of medical images with different wavelet transforms.

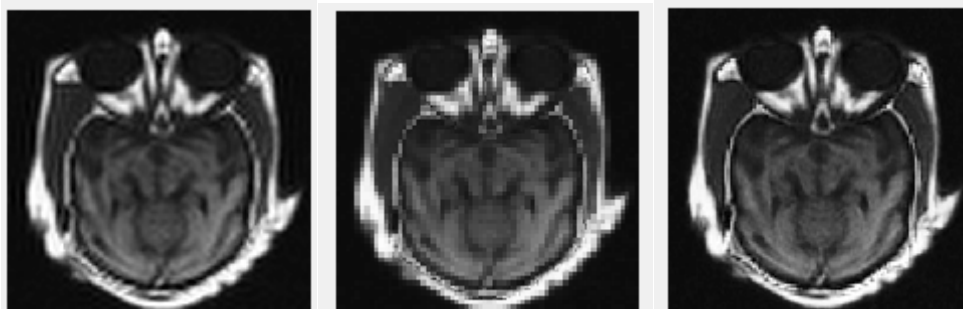


(a) MRI Image (b) CT Image

Figure 3(a-b): Source Images used for Fusion



(a) Daubechies(db) (b) Coiflets(coif) (c) Symlets(sym)



(d) Dmeyer(dmey)

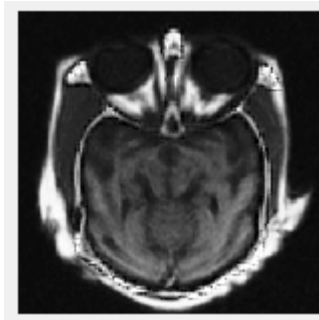
(e) Biorthogonal(bior)

(f) Reverse Bior(rbio)

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(g) Haar(haar)

**Figure 4(a-g): Wavelet Transform based Fused Images**

Throughout the analysis, second level decomposition with max-max wavelet coefficients is used. The performance of the individual fusion method is recorded using the different performance parameters which are shown in Table 1.

**Table 1: Image Fusion with different Performance Parameters**

Sl. No.	Wavelets	Entropy	Standard Deviation	RMSE	NAE	PSNR in dB
1	Db	15.9048	61.3113	58.4737	1.0006	13.3712
2	Coif	15.9276	61.3202	58.4739	1.0006	13.3711
3	Sym	15.9997	61.3369	58.4735	1.00059	13.3713
4	Dmey	15.8664	61.2736	58.4742	1.0006	13.3711
5	Bior	10.1233	61.0669	58.4749	1.00065	13.3713
6	Rbio	12.2704	61.0682	58.4760	1.00068	13.3708
7	Haar	10.1233	61.2902	58.4739	1.00065	13.3713

### V. CONCLUSION

In this paper, different wavelets like db, coif, bior, sym, rbio, dmey, haar are used for image fusion. The image fusion of MRI and CT images is performed in MATLAB GUI. From the simulation output, it is clear that fused image is having the qualities of both the source images. Qualitative analysis of the fused image with reference to the performance parameters like entropy, standard deviation, PSNR, NAE, RMSE helps in selecting better fusion method. The symlets(sym) wavelet show high entropy, standard deviation and PSNR compare to other wavelet transforms. So the symlets(sym) wavelet with max-max coefficients are preferred over other wavelet based fusion methods.

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