

# FUSION OF MEDICAL IMAGES USING TRANSFORM TECHNIQUES

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**Abstract**— Medical image fusion is a method in which the information from many images of the same picture are registered and combined into single fused image, which provides more information, compared to each single source image and it provides more reliable result for the observers. Image fusion techniques are performed here using Discrete Wavelet transform, Contourlet transform and Curvelet transform. The fusion performance is evaluated on the basis of Peak Signal to Noise Ratio (PSNR), Structural Content (SC), Normalized Absolute Error (NAE) and Standard Deviation (SD).

**Index terms**- Discrete Wavelet Transform, Curvelet Transform, Contourlet Transform, Quantitative Metrics.

## I. INTRODUCTION

Image fusion is a technique of combining data from many images of the same pictures into single fused image, which provides extra information, compared to each single source image and can provide more reliable and greater result for the observers. Different radiometric scanning techniques are used to examine or evaluate the inner body parts like Computer Tomography (CT), Position Emission Tomography (PET), and Magnetic Resonance Imaging (MRI) all these have their own merits and demerits.

Most of the work has been done by using Wavelet Transform for fusion. The Wavelet Transform applied to the two images preserve both spectral and spatial information and gives details of the image but it has limited directionality to deal with curved shapes. Curvelet transform is the solution that has the ability to deal with curved shapes. So, Curvelet based algorithm which is used for the extraction of edge information and to analyze the fusion of the images. Wavelet Transform cannot provide directionality and anisotropy. To overcome this problem, Contourlet transformation was developed. Contourlet transform is one which can efficiently represents the textures and contours which are there in the images.

## II. IMAGE FUSION METHODS

### A. Discrete Wavelet Transform

Wavelet Transform is one of the mathematical tool that can be used for multiscale approach, suited to manage different

image resolutions. DWT is of particular interest, which applies 2-channel filter bank along with down sampling repeatedly to the low-pass band. Finally, the wavelet depiction consists of high-pass bands and low-pass band at lower resolution that are derived at every step. Discrete Wavelet transform is known as invertible and non-redundant. The Discrete Wavelet Transform is a spatial domain decomposition which provides an elastic multiresolution study of an image [1]. In Two Dimensional DWT, One Dimensional (1-D) is carried out on the rows and then on columns of the signals by individually filtering and down-sampling to obtain 1-set of approximation coefficients LL and 3-set of detail coefficients (LH, HL, HH) as depicts in Figure 1. Low-pass and high-pass are denoted by 'g' and 'h' respectively.

To obtain a fusion decision map, wavelet transform image fusion is applied on each source images based on a set of fusion rules as depicts in Figure 2. In primary stage, the input images are broken-down into rows and column by low-pass and high pass filtering and then subsequently down-sampling at every stage to get approximation and detail coefficients. In final stage, Inverse Discrete Wavelet Transform is applied on fused coefficient to obtain a fused image.

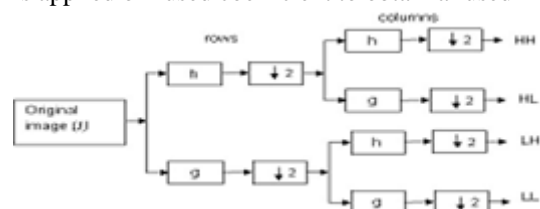


Figure 1: Structure of 2-D DWT

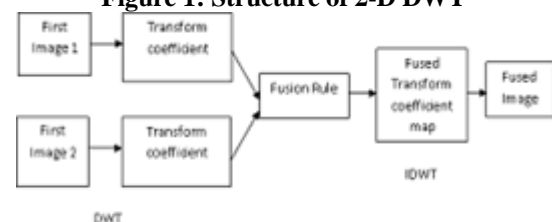
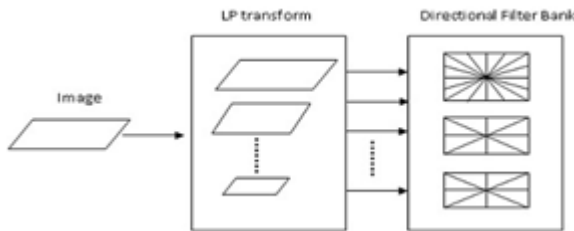


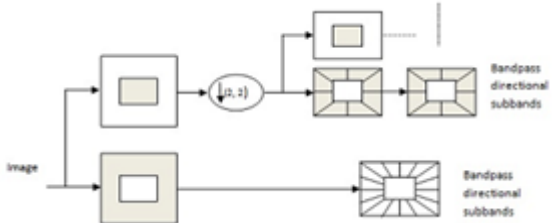
Figure 2: Image Fusion process using DWT

**B. Contourlet Transform**

An efficient directional multiresolution expansion which includes multiscale, local and directional contour segments is called as Contourlet Transform. Due to its anisotropy and directionality, it has a good performance in representing the features of original image such as lines, curves, contours and edges than Wavelet Transform. By integration of Laplacian pyramid with a directional expansion for images, Contourlet transform is obtained. The final result is an image expansion using common elements such as contour segments. Figure 3 depicts the functional block diagram of Contourlet Transform framework.

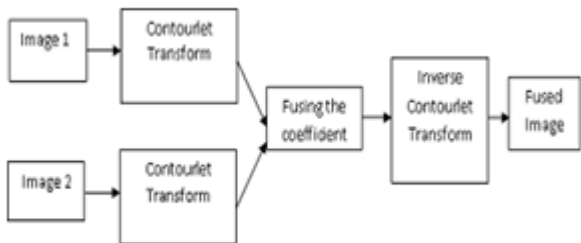


**Figure 3: Contourlet Transform framework [3]**



**Figure 4: Contourlet filter bank [3]**

Figure 4 depicts the Contourlet filter bank. By using Laplacian pyramid, multiscale decomposition is achieved and then directional filter bank is performed on each bandpass channel. The bandpass images are derived from Laplacian pyramid and are fed into a directional filter bank. The final output is PDFB (pyramidal directional filter bank) or double iterated filter bank structure, which is elastic in nature as it allows for a various number of directions at every scale. Finally, Contourlet Transform explores the edges in images which are localized in both direction and location. The block diagram of using Contourlet transform is as shown in Figure 5.



**Figure 5: Block diagram of Contourlet Transform**

**C. Curvelet Transform**

In 2000, Cands and Donoho, proposed Curvelet Transform, it was derived from Ridgelet Transform. It is a multiscale directional transform is helpful for the study of curve shape substance in the images. As complex sequences of ridgelet

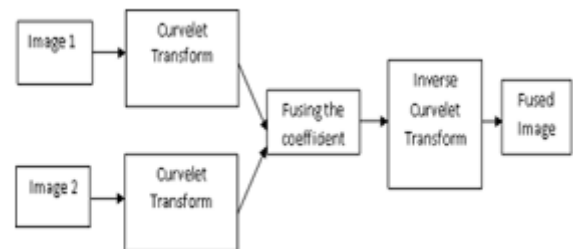
transform is used by Ridgelet-based curvelet transform, it is not efficient. In 2005, they newly developed Fast Discrete Curvelet Transform (FDCT) which is simple; less redundant and faster when compared to ridgelet transform [5].

**Fast Discrete Curvelet Transforms (FDCT)**

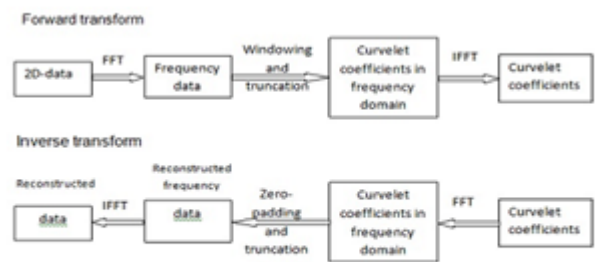
FDCT via unequally spaced Fast Fourier Transform (USFFT) is the first algorithm; it is performed on the LL band of the source image. Curvelet coefficients are obtained in this algorithm, by unevenly sampling the Fourier coefficients of an image using the equation (1). FDCT wedge-wrapping technique is based on the sequences of translation and wrapping of particularly selected Fourier samples is the second algorithm. This both the algorithm are used to provide the similar output but wrapping FDCT is faster and more instinctive [8]. It has time frequency localization properties of wavelet, high degree of directionality and also it covers whole frequency spectrum without loss of information [6].

$$C^D(j, l, k) = \sum_{0 \leq m < M, 0 \leq n < N} f[m, n] \cdot \varphi_{j,l,k}^D[m, n] \tag{1}$$

where  $f[m, n]$ ,  $0 \leq m < M, 0 \leq n < N$  is the input 2-D image.  $C^D(j, l, k)$  are the discrete curvelet coefficients,  $\varphi_{j,l,k}^D$  is the curvelet basis function,  $j$  is the scale, 2D FDCT wrapping technique is used as it is faster, simple and less redundant. The schematic representation of fusion using Curvelet transform is as shown in Figure 6.



**Figure 6: Block diagram of Curvelet Transform**



**Figure 7: Data flow construction of the FDCT forward And inverse transforms**

The implementation of FDCT Wrapping is based on the Fast Fourier Transform algorithm. Figure 7 depicts the information flow diagram of the forward and inverse wrapping Fast Discrete Curvelet Transform. Firstly, the 2D data is changed into the frequency domain by using forward FFT. Then, the changed data are multiplied with a set of window

functions. According to the requirements of Curvelet Transform, the windows shapes are defined, such as the parabolic scaling rule. By using inverse FFT from windowing data, the Curvelet coefficients are obtained. In the FDCT wrapping technique, before applying inverse FFT algorithm, the FFT coefficients are folded or wrapped into the rectangular shape.

### III. PERFORMANCE MEASURES FOR IMAGE FUSION

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

It is defined as the ratio between the maximum power of a signal and the magnitude of background noise. The higher PSNR value gives the better fused image. The PSNR of the fusion result is given by the following equation,

$$PSNR = 10 \log_{10} \left[ \frac{N^2}{\frac{1}{MN} \sum_{i=1}^m \sum_{j=1}^n (K_{ij} - I_{ij})^2} \right] \quad (2)$$

where ' $K$ ' is reference image and ' $I$ ' is the fused image of dimensions  $M * N$ , and ' $i$ ' and ' $j$ ' are pixel row and column index. ' $N$ ' represents maximum number of pixel in an image which takes value 255 for 8 bit gray-scale images.

#### B. Structural Content (SC)

It is a measure is used to compare both images in terms of a number of small image patches which are similar in

both the images. Image is said to be in good quality if the value of SC is less.

$$SC = \frac{\sum_{i=1}^m \sum_{j=1}^n (K_{ij})^2}{\sum_{i=1}^m \sum_{j=1}^n (I_{ij})^2} \quad (3)$$

where ' $K$ ' is reference image and ' $I$ ' is the fused image and ' $i$ ' and ' $j$ ' are pixel row and column index.

#### C. Normalized Absolute Error (NAE)

Large value of NAE indicates poor quality of the image. It is defined as follows,

$$NAE = \frac{\sum_{i=1}^m \sum_{j=1}^n (|K_{ij} - I_{ij}|)}{\sum_{i=1}^m \sum_{j=1}^n (I_{ij})^2} \quad (4)$$

where ' $K$ ' is reference image and ' $I$ ' is the fused image and ' $i$ ' and ' $j$ ' are pixel row and column index.

#### D. Standard Deviation (SD)

It is used to measure the gray values spread in an image and contrast of fused image. High SD value indicates better contrast of the image.

### IV. RESULTS AND DISCUSSIONS

Medical Images like Magnetic Resonance Image (MRI), CT images or PET images of the same set are registered using MATLAB R2009a. This project is implemented by using MATLAB R2009a; GUI model is as shown in Figure 8.

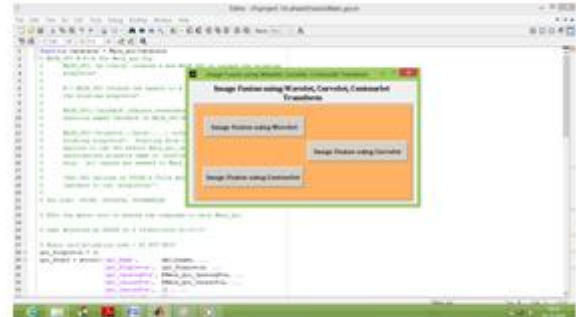
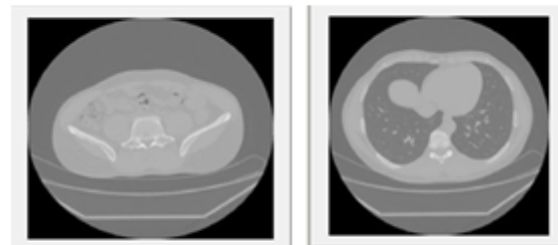


Figure 8: The GUI implementation of project.

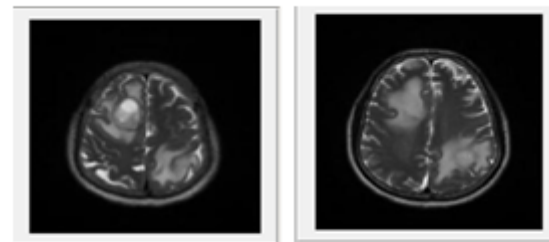
#### Input Images:



(a)

(b)

Figure 9: Input Images of set 1 (a) and (b) CT images of Abdomen



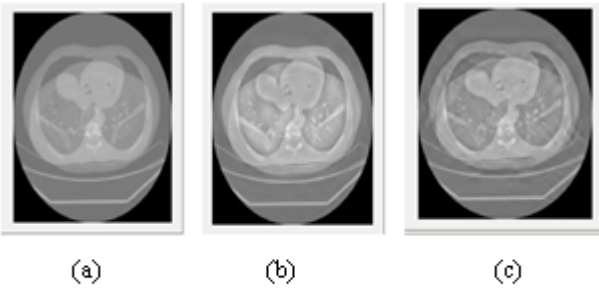
(a)

(b)

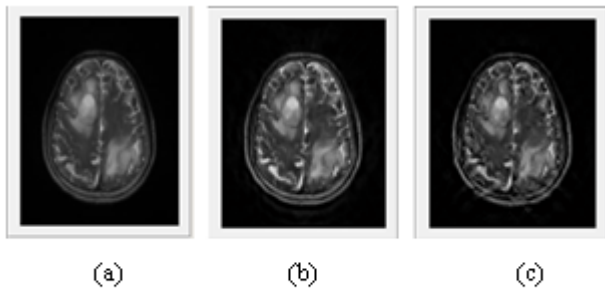
Figure 10: Input Images of set 2 (a) and (b) MRI images of Brain

Figure 9 (a) and 9 (b) shows the registered input CT images of the abdomen and Figure 10 (a) and 10 (b) shows the registered input MRI images of the brain respectively.

**Output Images for Registered Input Images of set 1 and set 2:**



**Figure 11: Fused Images for the Input Images of set 1 (a) DWT method (b) Curvelet Transform and (c) Contourlet Transform**



**Figure 12: Fused Images for the Input Images of set 2 (a) DWT method (b) Curvelet Transform and (c) Contourlet Transform.**

Figure 11 shows the registered input images set 1 of abdomen used for image fusion. Figure 11 (a), 11 (b) and 11 (c) shows fused output images for input images using DWT method, Curvelet Transform and Contourlet Transform respectively.

Figure 12 shows the registered input images set 2 of brain used for image fusion. Figure 12 (a), 12 (b) and 12 (c) shows fused output images for input images using DWT method, Curvelet Transform and Contourlet Transform respectively.

**Table 1: Statistical Analysis of Different Image Fusion Methods for Input Images of set 1**

Fusion Method	Parameters			
	PSNR(dB)	SC	NAE	SD
DWT Method	25.725	1.010	0.992	60.522
Curvelet Transform	23.028	0.878	0.086	66.034
Contourlet Transform	25.169	1.006	0.078	61.03

**Table 2: Statistical Analysis of Different Image Fusion Methods for Input Images of set 2**

Fusion Method	Parameters			
	PSNR(dB)	SC	NAE	SD
DWT Method	24.557	1.095	0.968	37.812
Curvelet Transform	22.563	0.796	0.331	44.31
Contourlet Transform	22.7108	0.980	0.340	41.011

Table 1 and 2 represents a evaluation of the test results of image fusion by three different methods in terms of PSNR, Structural content (SC) Normalized Absolute Error (NAE) and Standard deviation (SD). It is observed Curvelet-based method and Contourlet-based method are better for image fusion when compared with Discrete Wavelet-based method (DWT).

**V. CONCLUSION**

Fusion of two or more medical images improves the view and adds information of both anatomical and physiological in a single image. Two different images are fused by using three different image fusion methods like DWT, Contourlet and Curvelet Transform. These proposed algorithms achieve significant results. A comparative study has been carried out among these three fusion methods. From Table 1 and 2, it can be concluded that while comparing with DWT, Curvelet Transform and Contourlet Transform methods are better for image fusion. As that the fused image contains extra information from the input images which could be used for proper diagnosis.

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