

# Comparison of Fusion Techniques applied to Medical Images: Discrete Wavelet Transform and Fast Discrete Curvelet Transform Using Wrapping Technique

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**Abstract**— Image fusion is an important research topic in many related areas such as medical imaging, microscopic imaging, remote sensing, computer vision and robotics. The term image fusion is an approach to extraction of information acquired in several domains. The purpose of this paper is to obtain an image with more detailed information from two complementary featured images. Wavelet based image fusion technique is useful for objects with point singularity and it has limited directivity and does not provide information about edges clearly. Whereas curvelet based fusion technique is very efficient in representing curve-like edges. Now-a-days image fusion is used in medical imaging, in this paper the medical images, MRI (Magnetic Resonance Image) and CT (Computed Tomography) are fused using discrete wavelet transform and fast discrete curvelet transform using wrapping technique. CT image and MRI image gives the complimentary information which is helpful for diagnosis of disease. The proposed algorithm combines Discrete Wavelet Transform and Fast Discrete Curvelet Transform based image fusion which gives optimal sparse representation and reconstruction of organs with edges and make image smoother. This approach is further optimized and compared visually and statistically such as Entropy, MSE and PSNR.

**Index Terms**— CT Image, Discrete Wavelet Transform, Fast Discrete Curvelet Transform, Frequency Wrapping, Image Fusion, MRI Image.

## 1 INTRODUCTION

The objective of the image fusion is to fuse CT image and MRI image of the same part of body or same organ and obtain a single image containing more information of denser tissue as well as softer tissue about that organ. Image fusion is the process of data fusion.

Merging two images of the same scene to form a single image with as much information as possible. Image fusion technology is useful to improve patient diagnostics and therapeutics in preclinical and clinical imaging. Most of the transform based image fusion techniques utilize the transform coefficient of the input images are alone taken as an activity measure for the fusion rule criterion. Many image fusion techniques have been developed using Principal Component Analysis (PCA) transform, Wavelet Pyramid, Wavelet filters, etc. Wavelets used in image fusion are classified into three types orthogonal, Bi-orthogonal and A'trous or non-orthogonal wavelet [1]. In 1982 Jean Morlet Introduced the concept of Wavelet, has good time-frequency characteris

signal contain local information of an image [12] and wavelet transform has limited directivity and can't be extended to multi-dimension. In image fusion technique a special member of multiscale geometric transforms is the curvelet transform which was developed in the last few years in an attempt to overcome inherent limitations of traditional multiscale representations such as wavelet transform [3][11]. Conceptually, the curvelet transform is a multiscale pyramid with many directions and positions at each length scale, and needle-shaped elements at fine scales. Curvelets have useful geometric features that set them apart from wavelets [2].

To overcome this limitation, E. J. Candes and D. L. Donoho put forward Curvelet Transform theory in 2000 [3]. The curvelet transform is a multiscale directional transform that gives optimal nonadaptive sparse representation of organs with edges and it consist of special filtering process, it could fit image properties well [2]. The first generation curvelet transform used a complex series of steps involving the ridgelet analysis of radon transform of an image. The performance was exceeding slow [8]. Then E.J. Candes put forward Fast Discrete Curvelet Transform (FDCT) that was the Second Generation Curvelet Transform (2GCT) in 2005 [4]. The second generation transform discarded the use of the ridgelet transform, thus reduced the amount of redundancy in the transform and increased the speed considerably [8].

## 2 EXISTING METHOD

Image fusion can be defined as the process by which two input images or some of their features are combined together to form a single image. Image fusion using wavelet analysis

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tics. Wavelet transform are based on small waves, called wavelets, of varying frequency and limited time duration [10]. The wavelets perform well only at representing point singularities since they ignore the geometric properties of object and do not exploit the regularity of edges [11]. Wavelet analysis is originally introduced in order to improve time-frequency characteristic of signal. Wavelet transform of a

is an exciting new method for solving difficult problems in image processing. Non-stationary signals are analysed using wavelet transform. Wavelets also allow filters to be constructed for stationary and non-stationary signals. Wavelets classified into three categories Orthogonal, Bi-orthogonal and A'trous or non-orthogonal.

In the discrete orthogonal wavelet decomposition, an input image is decomposed at different scales into a lower resolution image and three detail images. This is done with a uniform sampling of two-dimensional convolution product. Orthogonal wavelet transform has unitary transform and gives only orthogonal matrices, whereas bi-orthogonal wavelet transform gives invertible matrices as well as gives the perfect reconstruction of input images. For bi-orthogonal wavelet filter, the length of low pass filter and high pass filter do not have the same length. The low pass filter used in image fusion is always symmetrical while high pass filter either symmetrical or non-symmetrical. A'trous transform is a non-orthogonal transform i.e. different from orthogonal and bi-orthogonal transform it is stationary and redundant transform [1]. In this transform down sampling is not implemented during the process of wavelet transform, due to the down-sampling in each decomposition step which may cause a large no of artifact when reconstructing an image after modification of its wavelet coefficient. Because of its shift invariance property, performance can be improved significantly by removing the decimation step in wavelet transform.

### 3 PROPOSED METHOD

In this paper a new method is proposed by combining Discrete Wavelet Transform and fast Discrete Curvelet Transform via wrapping technique. To overcome the missing directional selectivity of discrete wavelet transforms, multiresolution geometric analysis, curvelet transform is used in this paper. The curvelet transform is a multiscale directional transform that gives optimal nonadaptive sparse representation of organs with edges. The second generation curvelet transform is very efficient tool for medical image fusion.

#### 3.1 Block Diagram of Proposed Method

Figure 1 shows the block diagram proposed image fusion method. Firstly two complementary feature source images i.e. CT image and MRI image are registered then the 2D discrete wavelet transform of the two registered input images are computed. Discrete wavelet transform decompose input images into proper level.

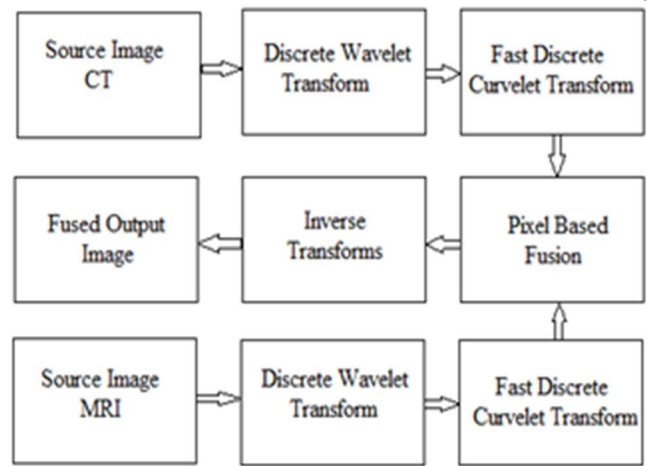


Fig. 1 Block Diagram of proposed method

One low frequency approximate component and three high frequency detail components will be acquired in each sub-band as shown in fig. 2. Fast discrete curvelet transform is implemented using the wrapping technique which is in the spectral domain utilizes the advantage of Fast Fourier Transform (FFT). Wrapping based curvelet transform is a multiscale pyramid which consists of different orientations and positions at a low frequency level. During FFT, both the image and curvelet at given scale and orientation are transformed into the FT domain. At the end we obtain a set of curvelet coefficients and these coefficients are fused using pixel level fusion rule. In pixel level fusion rule maximum value of pixel is chosen. After fusion inverse transforms (IDWT and IFDCT) are computed and fused image is reconstructed. The performance of the proposed algorithm can be evaluated using entropy, RMSE and PSNR.

#### 3.2 Algorithm of Proposed Image Fusion Method

In medical imaging, CT and MRI image both are tomographic scanning images for medical diagnosis. CT provides the best information on denser tissue with less distortion and the brightness of bones is higher in CT image while MRI provides the better information on soft tissue with more distortion and the brightness of tissues is higher in MRI. CT and MRI image have complementary features. Here fusion of two brain image plays an important role for diseases diagnosis which combines both CT image of brain and MRI image of brain and it form a single image which provides more information about denser tissue as well as soft tissues. Images can be fused at different levels; in proposed method pixel level image fusion is adopted.

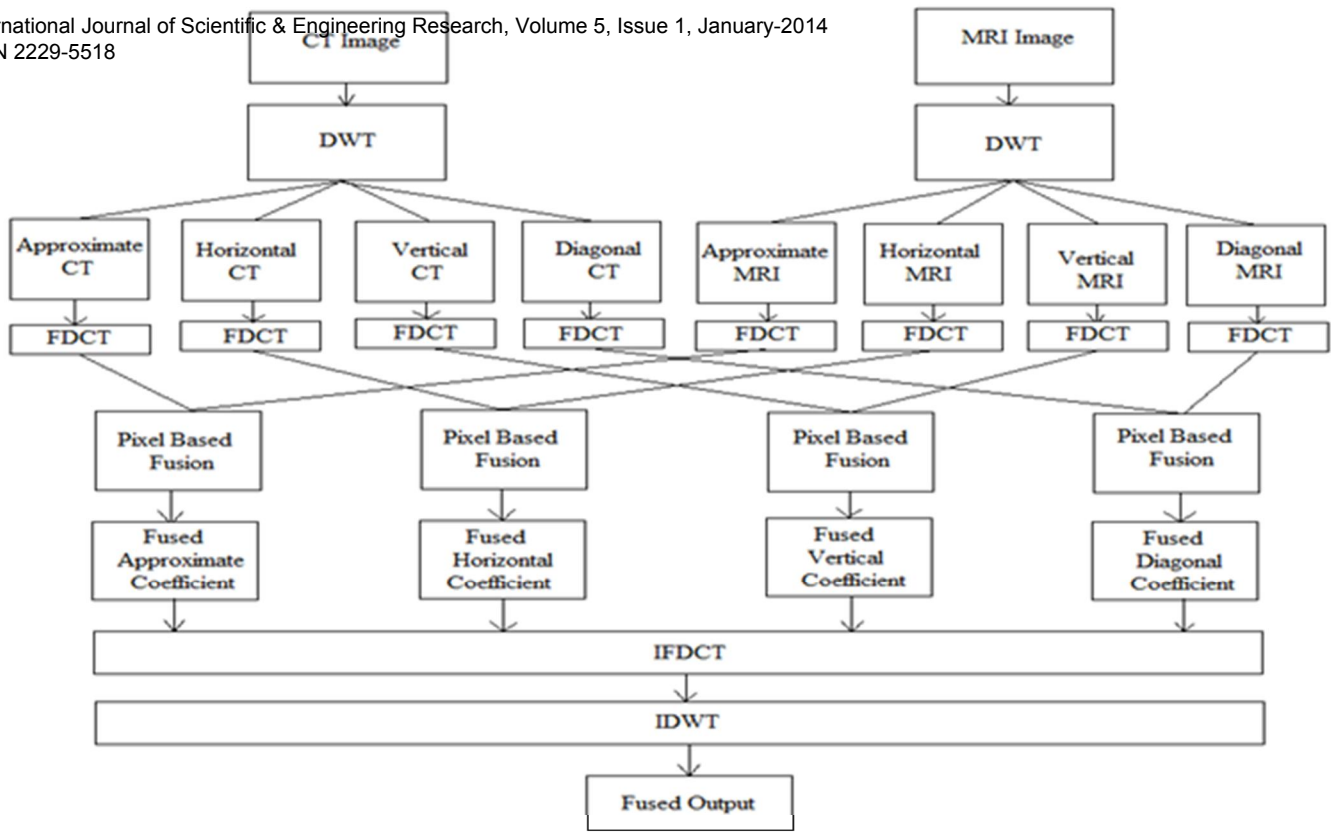


Fig. 2 Pixel Based Image Fusion Using discrete wavelet transform and fast discrete curvelet transform

The actual flow of proposed method is as shown in fig. 2

Following are the steps involved in proposed fusion algorithm:

1. Register the same size 2D CT image and 2D MRI image of the same organ and then resample both input images to correct original images and distortion so that both of them have same probability distribution.
2. Perform independent 2D-DWT decomposition of the two images until to get approximation (LL) and detail (LH, HL and HH) coefficients.
3. The new implementation of fast discrete curvelet transform, based on wrapping of Fourier samples, takes a 2D image as input in the form of a Cartesian array  $I[m, n]$ , where  $0 \leq m < M, 0 \leq n < N$  and  $M, N$  are dimensions of the array.
4. Apply the 2D FFT to CT and MRI image subbands and obtain Fourier sample  $I_1[n_1, n_2]$  and  $I_2[n_1, n_2]$  where  $-n/2 < n_1, n_2 < n/2$ .
5. For each scale  $s$  and angle  $a$  form the product,  $\tilde{W}_{s,a}[n_1, n_2] I[n_1, n_2]$ . Where  $\tilde{W}$  is the Cartesian window.
6. Wrap this product around the origin and obtain

$$I_{s,a}[n_1, n_2] = R(\tilde{W}_{s,a} \hat{I})[n_1, n_2]. \text{ Where, the range for } n_1 \text{ and}$$

$n_2$  is  $0 \leq n_1 < L_{1,s}$  and  $0 \leq n_2 < L_{2,s}$  and the  $\theta$  in the range  $(-\pi/4, \pi/4)$ .

7. Apply the 2D inverse FFT to each  $I_{s,a}$  hence the collecting discrete coefficient equation (1)

$$C^D(s, a, k_1, k_2) = \sum_{\substack{0 \leq m < M \\ 0 \leq n < N}} I[m, n] \phi^D_{s,a,k_1k_2} \quad (1)$$

8. The frequency response of a curvelet is a trapezoidal wedge and the wrapping of this trapezoidal wedge is done by periodically tiling the spectrum inside the wedge and then collecting the rectangular coefficient area in the origin.

9. Select maximum valued pixel based algorithm for approximations and details coefficient in the two source images CT and MRI is given by,

$$\begin{aligned} LL &= \text{Maximum}(LL_1(n_1, n_2), LL_2(n_1, n_2)) \\ LH &= \text{Maximum}(LH_1(n_1, n_2), LH_2(n_1, n_2)) \\ HL &= \text{Maximum}(HL_1(n_1, n_2), HL_2(n_1, n_2)) \\ HH &= \text{Maximum}(HH_1(n_1, n_2), HH_2(n_1, n_2)) \end{aligned}$$

10. Finally, the fused image is obtained by applying inverse fast discrete curvelet transform and inverse discrete wavelet transform and then fusion results are compared visually and statistically such as entropy, mean Square error and peak signal to noise ratio.

#### 4 QUANTITATIVE ANALYSIS

Proposed method performance evaluation is done by taking entropy, MSE and PSNR. Results of existing method that is wavelets used in fusion such as orthogonal, bi-orthogonal and a'trous are compared with proposed method using three parameters:

1. Entropy

The entropy of an image is a measure of information content, for better fused image the entropy should have a large value.

$$\text{Entropy} = -\sum P_i \log_2 P_i \tag{2}$$

2. MSE (Mean Square error)

It is most easily defined via the mean squared error (MSE) which for two M X N images S and F, where image S is considered a source image and F is the fused image.

$$\text{MSE} = \frac{\sum_{i=1}^M \sum_{j=1}^N [I(i, j) - F(i, j)]^2}{M \times N} \tag{3}$$

3. Peak Signal to Noise Ratio

The PSNR is the most commonly used as quality of reconstruction of fused image. It is defined as,

$$\text{PSNR} = 10 \log_{10}(255^2/\text{MSE}) \tag{4}$$

Where, 255 is the maximum pixel value of the image when the pixels are represented using 8-bit per sample.

#### 5 EXPERIMENTAL RESULTS

For visual evaluation, we consider natural appearance, brilliance contrast and presence of complementary features and enhancement of common features. Fig.3a) and b) represents the CT and MRI images of brain of the same person respectively. In the MRI image the inner contour missing but it provides better information on soft tissue. In the CT image it provides the best information on denser tissue with less distortion, but it misses the soft tissue information. Fig.3 c) shows the result of orthogonal wavelet fusion technique which is by combining of CT and MRI images. The orthogonal wavelet fused image have information of both images but have more aliasing effect. Fig.3 d) shows the result of bi-orthogonal wavelet fusion, when we compare bi-orthogonal wavelet with orthogonal wavelet it shows soft tissues information which are not shown in fig. 3 c) i.e. at the left and right side of the inner part. Fig.3 e) shows the result of A'trous wavelet (non-orthogonal wavelet) based fusion. The fusion result of non-orthogonal wavelet gives better information on soft tissues and denser tissues.

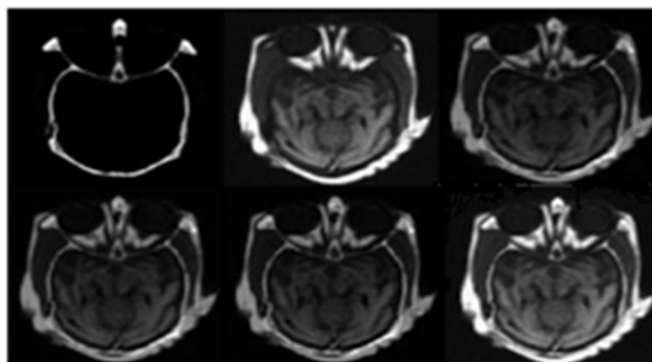


Fig.3 a) CT image b) MRI image c) Orthogonal fusion  
 d) Bi-orthogonal fusion e) A'trous Fusion f) DWT & FDCT Fusion

Fig.3 f) contains information about edges and it preserves spectral information of original image. In addition to the visual analysis, we extended our investigation to a quantitative analysis. The experimental results are analyzed based on the combination entropy, MSE and PSNR. Proposed image fusion technique gives the highest value of PSNR and entropy as shown in table 1.

TABLE 1  
 Quantitative Analysis of Fusion Methods

Fusion Methods	Entropy	PSNR	MSE
Orthogonal Transform	0.00026	29.333	75.8032
Biorthogonal Transform	0.00186	29.318	76.0792
A'trous Transform	0.28775	31.972	41.2914
DWT and FDCT	6.7504	44.022	2.5753

#### 6 CONCLUSION

This paper puts forward image fusion algorithm based on discrete wavelet and fast discrete curvelet transform using wrapping technique. It includes the multiresolution analysis ability in discrete wavelet transform and better direction identification ability for the curves and edges in discrete curvelet transform. In this paper proposed image fusion algorithm gives the better fusion results visually and statistically.

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