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A COMPARISON ON MEDICAL IMAGE FUSION OF CT AND MRI IMAGES USING TRANSFORM DOMAIN TECHNIQUES

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Abstract

This paper presents a comparative analysis on medical image fusion of CT and MRI images using various transform domain techniques. Image fusion is the process of combining two images to form a single image. The new image will be more informative than these two input images. CT image provides better information about denser tissue and it is not good for soft tissues. MRI image provides better information about the blood vessels, brain, heart, spinal cord and other internal organs and it is less accurate for bones. These two images are fused into a new image to improve the information content for diagnosis. Varieties of algorithms such as Discrete Wavelet Transform, Pyramid Wavelet Transform, Stationary Wavelet Transform, Curvelet Transform and Contourlet Transform are available to fuse two images. The fusion rule, Select-Maximum is used. The work is implemented using MATLAB. The results are compared by using various performance measures such as Image Quality Index (IQI), Mutual Information (MI), Fusion Index (FI),Fusion Symmetry (FS), Fusion Factor (FF), Standard Deviation (SD), Entropy (EN), Root Mean Square Error(RMSE), Peak Signal to Noise Ratio (PSNR).

Keywords: Modality, CT, MRI, fusion, transform, DWT, SPW, SWT, Curvelet, Contourlet

I. INTRODUCTION

Medical imaging offers powerful tools that help physicians and surgeons in the diagnosis process. Today, there are many medical modalities that give important information about different diseases. Complementary information are offered by the modalities CT, MRI etc. The CT image provides best information about denser tissue and MRI image offers better information on soft tissue. These complementarities have led to idea that combining images acquired with different medical devices will generate an image that can offer more information than each other separate.The composite image not only provides salient information from both images but also reveals the position of soft tissue with respect to the bone structure. In this way, the obtained image can be very useful in the diagnosis process, and that's why the image fusion has become an important research field [1].

There are two basic requirements for image fusion. First, fused image should possess all possible relevant information contained in the source images; second, fusion process should not introduce any artifact, noise or unexpected feature in the fused image. So image fusion should be carefully performed without any loss of information.

The remaining part of the paper is organized as follows: Section II presents the categories of image fusion methods. Section III describes various transform domain fusion methods, Section IV explains various performance measures used in this work, Section V analyze and compares the performance of some recent fusion and transform methods and finally Section VI gives the conclusion.

II. CATEGORIES OF IMAGE FUSION METHODS

The image fusion techniques can be organized into three main categories. **Primitive fusion schemes**, such as averaging, weighted averaging and global Principal-Component-Analysis (PCA), are performed in the spatial domain. Even though these methods are easy to implement, they pay the expenses of reducing the contrast and distorting the spectral characteristics. To solve these problems, more refined fusions in the **transform domain** are used. They employ properties like multi-resolution decomposition. It decomposes images at different scale to several components, which account for important salient features of images. Therefore, it enables a better performance than those performed in the spatial domain. The methods in the third category utilize **statistical** ways, such as Bayesian optimization to obtain the fused image; however, it suffers from a significant increase of computational complexity [2].

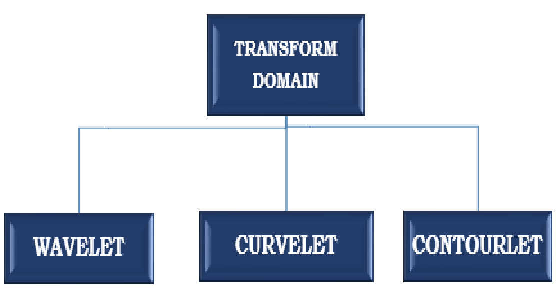


Fig.1 Transform domain fusion methods

In this paper we are comparing the performance of various transform domain fusion methods.

III. TRANSFORM DOMAIN METHODS

In Transform Domain method, the image is transformed in to frequency domain [3]. Some of the transform domain fusion methods are,

- Discrete Wavelet Transform (DWT)
- Stationary Wavelet Transform (SWT)
- Steerable Pyramid Wavelet Transform (SPT)
- Curvelet Transform
- Contourlet Transform

A. Discrete Wavelet Transform (DWT)

Wavelet transforms are multi-resolution image decomposition tool that provide a variety of channels representing the image feature by different frequency sub-bands at multi-scale. When decomposition is performed, the approximation and detail component canbe separated 2-D Discrete Wavelet Transformation (DWT) converts the image from the spatial domain to frequency domain. The image is divided by vertical and horizontal lines and represents the first-order of DWT, and the image can be separated with four parts those are LL1, LH1, HL1 and HH1 [4].

B. Stationary Wavelet Transform (SWT)

The Discrete Wavelet Transform is not a time invariant transform. The way to restore the translation invariance is to average some slightly different DWT, called the stationary wavelet transform (SWT). It does so by suppressing the down-sampling step of the decimatedalgorithm and instead up-sampling the filters by inserting zeros between the filter coefficients.

Stationary Wavelet Transform (SWT) is similar to Discrete Wavelet Transform (DWT) but the only process of down-sampling is suppressed that meansthe SWT is translation-invariant [5].

C. Steerable Pyramid Wavelet Transform (SPT)

Unlike most discrete wavelet transforms, the steerable pyramid wavelet transform is a linear multi-scale, multi- orientation image decomposition method, which is non-orthogonal and over complete. The decomposition of input image is performed resulting in low pass sub band and high pass sub band using steerable filters. The steerable pyramid representation is translation and rotation invariant. The primary drawback is that the representation is over complete by a factor of 4k/3, where k is the number of orientation bands [6].

D. Curvelet Transform

A curvelet transform is a multi-scale transform [7] which differs from other directional wavelet transforms in that the degree of localization in orientation varies with scale. Curvelets are an appropriate basis for representing images, which are smooth apart from singularities along smooth curves, where the curves have bounded curvature. When the image is of the right type, curvelets provide a representation that is considerably sparser than other wavelet transforms. This can be quantified by considering the best approximation of a geometrical test image that can be represented using only n wavelets, and analyzing the approximation error as a function of n.

E. Contourlet Transform

Different from the curvelet which is first developed in continuous domain and then is discretized for sampled data, contourlet transform (CT), introduced by Do and Vetterli, starts with a discrete- domain construction [8]. This transform is more suitable for constructing multi-resolution and multi-directional expansions using non-separable Pyramid Directional Filter Banks (PDFB) with small redundancy factor.

The Laplacian pyramid is first used to capture the point discontinuities, and then a directional filter bank is used to link point discontinuities into linear structures. [9].

The wavelet transform is good at isolating the discontinuities at object edges, but cannot detect the smoothness along the edges. Moreover, it can capture limited directional information. The contourlet transform can effectively overcome the disadvantages of wavelet. Contourlet transform is a multi-scale and multi-direction framework of discrete image.

IV. PERFORMANCE MEASURES

Performance measures are used essential to measure the possible benefits of fusion and also used to compare results obtained with different algorithms. Some of the performance measures considered in this paper are

- Fusion Index (FI)
- Fusion Symmetry (FS)
- Fusion Factor (FF)
- Root Mean Square Error(RMSE)

A. Fusion Index (FI)

The fusion index (FI) is defined as

$$FI = I_{AF} / I_{BF}$$

Where I_{AF} is the mutual information index between multispectral image and fused image and I_{BF} is the mutual information index between panchromatic image and fused image. The quality of fusion technique depends on the degree of fusion index.

B. Fusion Symmetry (FS)

Fusion Symmetry is a measure of symmetry of the fused image and is given by

$$FS = abs\,(\frac{I_{AF}}{I_{AF}+I_{BF}} - 0.5)$$

Where IAF and IBF are mutual information between source images and fused image. The quality of fusion technique depends on the degree of Fusion symmetry. Since FS is the symmetry factor, when the sensors are of good quality, FS should be as low as possible so that the fused image derives features from both input images. If any of the sensors is of low quality then it is better to maximize FS than minimizing it. **Low** value of fusion symmetry indicates the goodness of the fusion algorithm.

C. Fusion Factor (FF)

Given two images A and B, and their fused image F, the Fusion factor (FF) is

$$FF = IAF + IBF$$

Where IAF and IBF are the MIM values between input images and fused image. A **higher** value of FF indicates that fused image contains moderately good amount of information present in both the images.

D. Root Mean Square Error (RMSE)

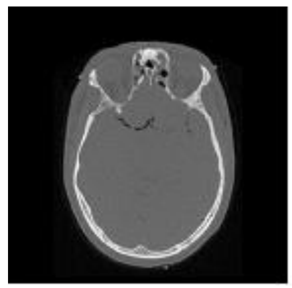
Root Mean Square Error (RMSE) between the fused image and original image provides error as a percentage of mean intensity of the original error. The RMSE value is calculated as:

$$RMSE= \sqrt{\frac{1}{mn}\sum_{i=1}^{m} \quad \sum_{j=1}^{n}(R(i,j)-(F(i,j))2}$$

Where R(i, j) is the reference image and F(i, j) is fused image, and m and n are image dimensions. **Smaller** the value of the RMSE, better the performance of the fusion algorithm.

V. EXPERIMENTAL RESULT

The input images are CT and MRI images. They are fused using the transform domain fusion methods such as Discrete Wavelet Transform (DWT), Stationary Wavelet Transform (SWT), Steerable Pyramid Transform (SPT),Curvelet and ContourletTransform fusion algorithms and the Select-Maximum fusion rule is applied. The input images are shown in Figure 2(a) and 2(b). The corresponding outputs are shown in the Figure2(c), (d), (e), (f), (g), (h)



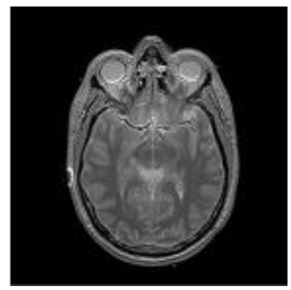
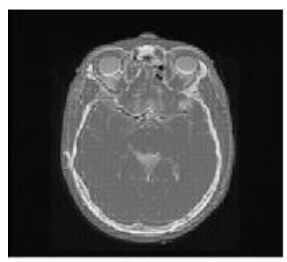
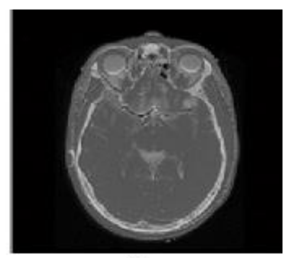


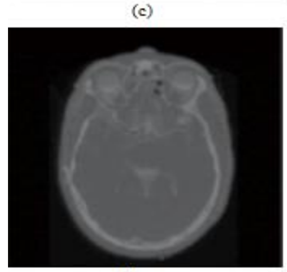
Fig.2(a) CT Image (b) MRI Image



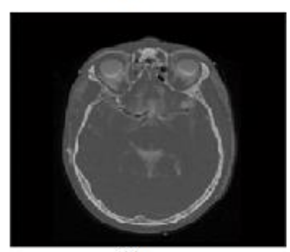
(c)



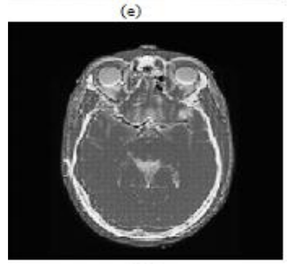
(d)



(e)



(g)



(h)

2 (c) Fused Image by DWT (d) SWT (e)SPT (f) Curvelet
(g) Contourlet

The values of performance measures of the fused image by using various transform domain methods are given in the following Table:1

FUSION METHODS	FI	FS	FF	RMSE
DWT	2.0872	0.0511	3.9667	26.3356
SWT	2.0956	0.1586	3.8683	26.0729
SPT	2.2275	0.168	2.566	28.7875
CVT	3.0119	0.0228	4.8683	11.4919
CNT	2.9291	0.0209	5.0644	11.4656

Table 1. Performance Evaluation of Fusion Results

The following figures Fig.3, Fig.4 and Fig.5 show the graphical representation of various performance measuresFI, FF,FS and RMSE respectively.

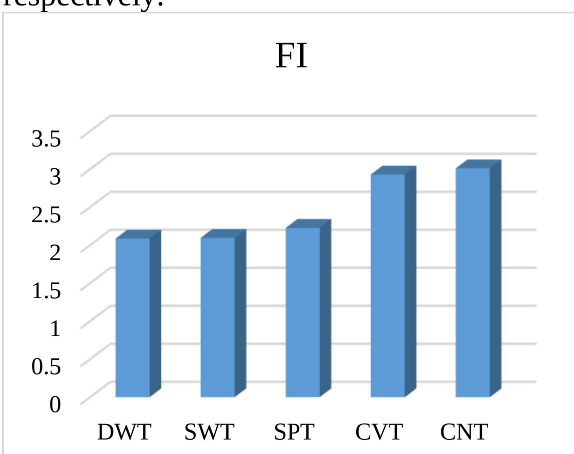


Fig.3 Performance Analysis in Respect to FI

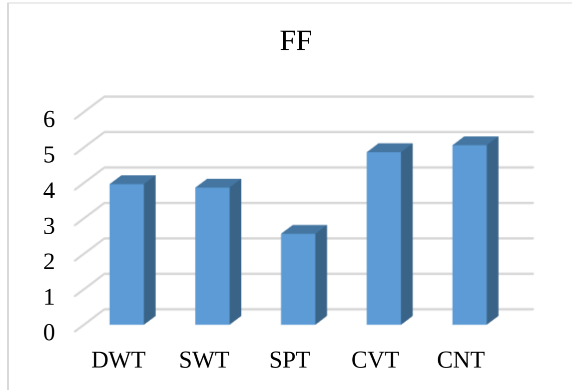


Fig.4 Performance Analysis in Respect to FF

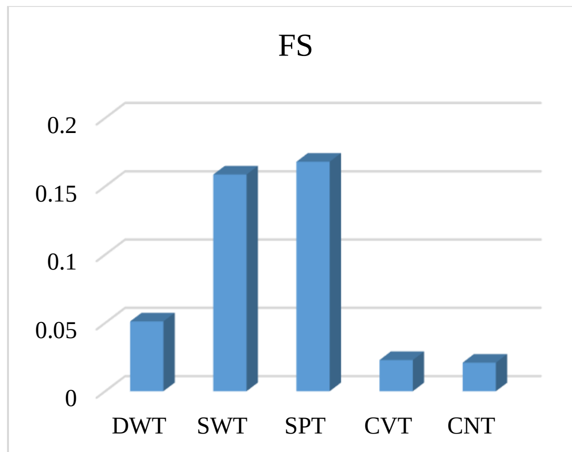


Fig.5 Performance Analysis in Respect to FS

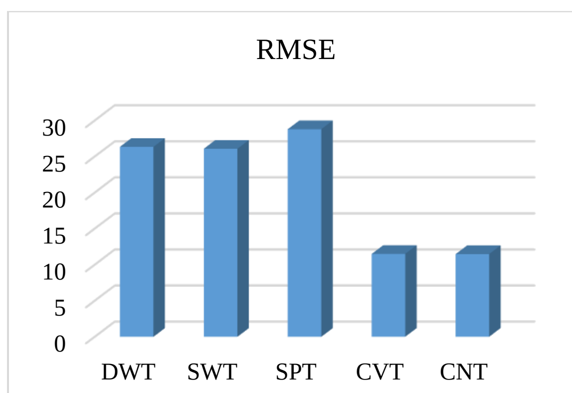


Fig.6 Performance Analysis in Respect to RMSE

From the graph, it is evident that the proposed method has higher values according to FI andFF has lower value according to RMSE and FS.So it is concluded that results obtained from the contourlet transform based fusion method performs better than DWT, SWT, SPT, Curvelet transform based fusion methods.

VI. CONCLUSION

The use of image fusion in the medical context is to improve confidence in diagnostics. From medical image fusion the clinicians can benefit from the complementarities of the different images to decide whether there is evidence showing the progression of the disease. In this paper, performance analysis is compared with different multi scale transforms such as Wavelet, Stationary Wavelet, Steerable Pyramid wavelet, Curveletand Contourletfor the fusion of multimodality images and proved that the contourletmethod provides better result.

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