Wavelet Transform Approach for Medical Image Fusion And Quality Analysis

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***Abstract*— This paper proposes wavelet transform based image fusion algorithm, after studying the principles and characteristics of the discrete wavelet transform. Medical image fusion used to derive useful information from multimodality medical images. The idea is to improve the image content by fusing images like computer tomography (CT) and magnetic resonance imaging (MRI) images, so as to provide more information to the doctor and clinical treatment planning system. This paper based on the wavelet transformation to fused the medical images. The wavelet based fusion algorithms used on medical images CT and MRI, The peak-to-peak signal-to-noise ratio (PSNR) method for measuring fusion effect. The result of fusion scheme based on wavelet transform compared with other fusion method.**

***Keywords*-Medical image; Wavelet Transform; Image Fusion; PSNR**

I. INTRODUCTION

The image fusion is the synthesis of multi source image information which is retrieved from the different sensors. It can synthesis the two or more images into one image which is more accurate, all-around and reliable. It can result in less data size, more efficient target detection, and target identification and situation estimation for observers. Also it can make the images more suitable for the task of the computer vision and the follow-up image processing. Image fusion refers to the techniques that integrate complementary information from multiple image sensor data such that the new images are more suitable for the purpose of human visual perception and the compute-processing tasks. The fused image should have more complete information which is more useful for human or machine perception. The advantages of image fusion are improving reliability and capability .As the clinical use of various medical imaging systems extends, the multi-modality imaging plays an increasingly important role in medical imaging field. Different medical images registered computed tomography (CT) and magnetic resonance imaging (MRI) Wavelets are a mathematic tool for hierarchical decomposing functions. After many successful applications in signal processing, wavelets have also been accepted as a powerful image processing technique among image fusion society. Wavelet transform can provide efficient localization in both space and frequency domains. Comparing with other multiscale transforms, wavelet transform is more compact, and able to provide directional information in the low-low, high-low, low-high, and high-high bands, and contains unique information at different resolutions. Image fusion based on wavelet transform can provide better performance than those based on other multiscale methods we list above. Wavelet transform has been already applied to image fusion. It is computed by the recursive application of low pass and high pass filters in each direction of the input image (i.e. rows and columns) followed by sub sampling.

On the other hand, the fusion methods of imagines based on wavelet transform decompose the image into low and high frequency parts, and the parts of low frequency contain the edge information, while the parts of high frequency contain the details. In the first level of decomposition, the losing information of low frequency parts can be captured by the related high ones. In the next level of decomposition, the parts of low frequency can be decomposed into lower frequency parts and higher frequency parts again. Similarly, in this level, the losing information of low frequency parts can be captured by high frequency again , and the rest can be deduced by analogy. Because the wavelet transform can only decompose the low frequency parts in farther and cannot decompose the high frequency parts in farther, wavelet decomposition in the imagine fusion will inevitably lose some details that captured by high frequencies. In this paper, the image fusion is performed at the pixel level, other types of image fusion schemes, such as feature or decision fusion, are not considered. We select two methods to experiment and to compare with. They are weighted average method and Wavelet-transform-based image fusion method. In this paper, we are mainly focusing on wavelet based image fusion approach.

There are some important requirements for the image fusion process:
The fused image should preserve

- All relevant information from the input images
- The image fusion should not introduce artifacts which can lead to a wrong diagnosis

A very important step must be realized before fusion process, namely image registration. Multimodality registration means the matching of the same scene acquired from different sensors.

II. WAVELET TRANSFORM

A. Definition

Given orthogonal scale function Ǿ (t) and wavelet function Ψ(*t*) [3], Second-scale relations as follows:

$$Ǿ(t) = \sqrt{2} \sum_{k} h_{0k} Ǿ(2t - k) \qquad 2.1$$

$$\psi(t) = \sqrt{2} \sum_{k} h_{1k} Ǿ(2t - k) \qquad 2.2$$

Where h_{0k} and h_{1k} are filter coefficients.

Fusion based on transforms has some advantages over other simple methods, like: Energy compaction, larger SNR, reduced features, etc. The transform coefficients are representative for image pixels. Wavelets are used for time frequency localization, and perform multi-scale and multiresolution operations. Discrete wavelet transform (DWT), transforms a discrete time signal to a discrete wavelet representation. It converts an input series x0, x1, .., x_m, into one high-pass wavelet coefficient series and one low-pass wavelet coefficient series (of length n/2 each) given by the formulas:

$$H_i = \sum X_{2i-m} . S_m (z) \qquad 2.3$$

$$Li = \sum X_{2i-m} . t_m (z) \qquad 2.4$$

$S_m(z)$ and $t_m(z)$ are called wavelet filters, k is the length of the filter,
And i = 0... . [n/2]-1.

The resolution of an image, which is a measure of amount of detail information in the image, is changed by filtering operations of wavelet transform and the scale is changed by sampling. The DWT analyses the image at different frequency bands with different resolutions by decomposing the image into coarse approximation and detail coefficients.

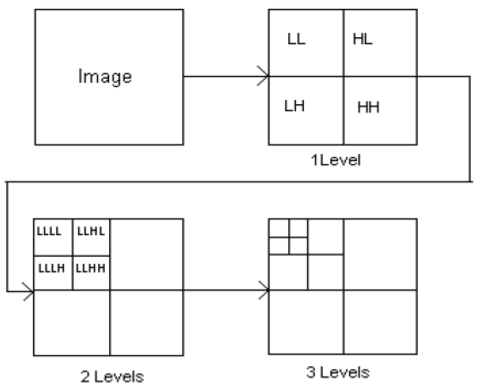


Figure 1: Image decomposition scheme using 2D DWT

Each image is decomposed by 2 levels using discrete wavelet transform. At every level are obtained two sets of coefficients, approximation (LL) and detail (HL, LH and HH).

III. IMAGE FUSION TECHNIQUE

In this paper, the image fusion is performed at the pixel level, which denotes a fusion process generating a single image containing more accurate description and more information than any individual original image. The fused image should be more suitable for the purpose of human visual perception, object detection, target recognition and other computer-processing tasks.

A) Image fusion algorithms

There are many algorithms for image fusion

1) Fusion Using Logical Operators

This technique of fusion information uses logical operators. One image is the reference image and it is not processed. From the second image is established a region of interest and the information from these images are then combined. The simplest way to combine information from the two images is by using a logical operator, such as the XOR operator, according to the following equation

$$I(x, y) = I_A(x,y)(1 - M(x, y)) + I_B(x,y)M(x, y)$$

Where $M(x, y)$ is a Boolean mask that marks with 1s every pixel, which is copied from image B to the fused image $I(x, y)$.

2) Fusion Using a Pseudo-color Map

According to this fusion technique, the registered image is rendered using a pseudo color scale and is transparently overlaid on the reference image. A pseudo-color map is defined as a correspondence of an (R, G, B) triplet to each distinct pixel value.

3) Image Fusion Based on Wavelet Transform

The original image can be decomposed to low frequent image and high frequent image by wavelet decomposition, and the low frequent image can be decomposed gradually, the decomposed sub-images comprise the spatial information of original images. The low frequent image reflects the approximation and evenness of original image, and concentrates the most information of original image; the pixel value of high frequent image fluctuate around zero, pixels of larger absolute value reflect the brightness sudden change character, representing the sudden change character of original image, and they correspond to edge or regional boundary .

B. Fusion rules

Fusion rules determine how the source transforms will be combined:
- Fusion rules may be application dependent - Fusion rules can be the same for all subbands or dependent on which sub-band is being fused There are two basic steps to determine the rules [2],

– compute salience measures corresponding to the individual source transform
– decide how to combine the coefficients after comparing the salience measures (Selection or averaging)
Fig. 3 presents a general fusion process using multi-level image decomposition.

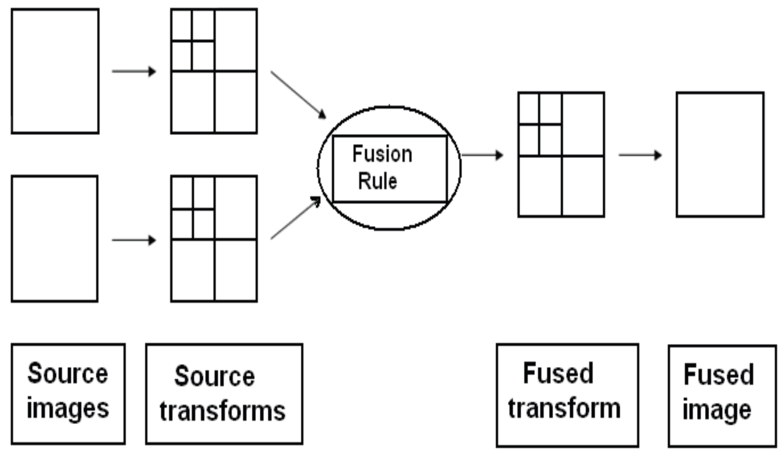
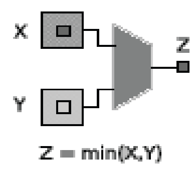


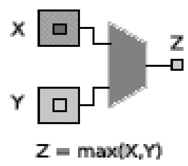
Figure3: Fusion process

There are many rules for image fusion. Some of them are very simple, like: MIN, MAX, MEAN, which use the minimum, maximum and mean values of the transform coefficients,

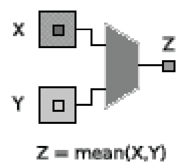
1) MIN METHOD:



2) MAX METHOD



3) MEAN METHOD



Some rules involve operations, like energy or edge. For these methods have to be used spatial filtering, like Energy filter or Laplacian operator edge filter.

The kernels for these two filters are presented in (4.a) and (4.b) respectively.

0	**1**	**0**
1	**2**	**1**
0	**1**	**0**

Figure 4.a) Energy filter kernel

$$\begin{matrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{matrix}$$

Figure 4.b) Laplacian operator edge filter kernel

C. The Scheme of Image Fusion

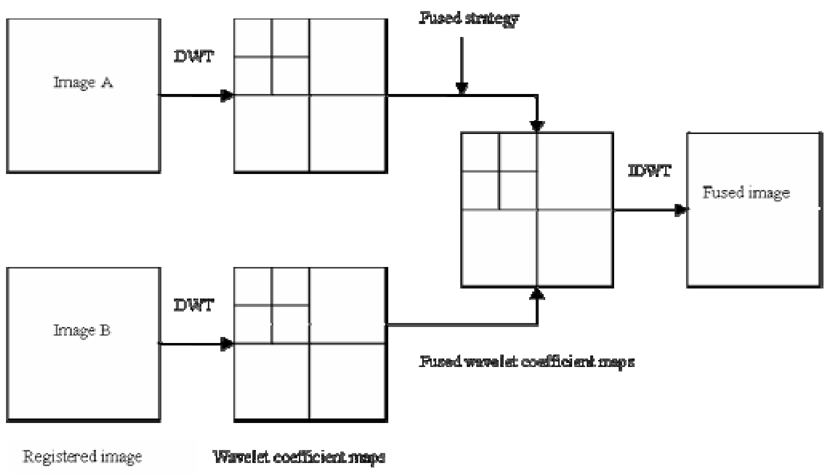


Figure 5: Image Fusion Process with Wavelet Transform

Figure 5 shows image fusion scheme based on wavelet transform [3], Discrete wavelet Transform is performed on registered images .This gives wavelet coeffients of both images. Using fusion rule wavelet coefficients are map to fused wavelet coefficient. In last stage IDWT is performed on fused wavelet coefficient to obtain the fused image.

D. Experimental Result

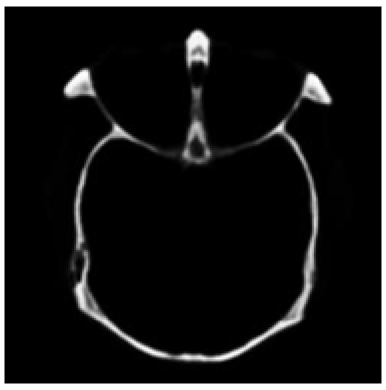


Figure a)CT Image

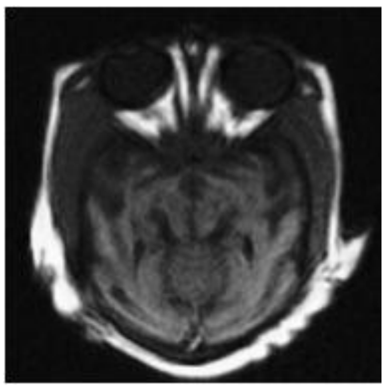


Figure b) MRI Image

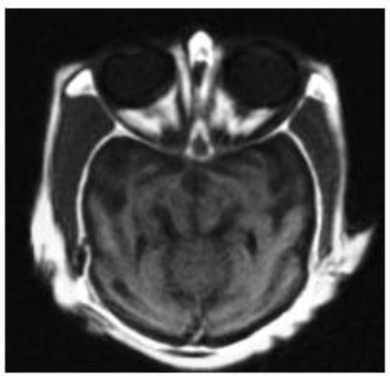


Figure c) Reference image

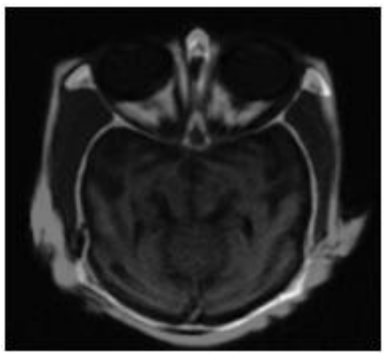


Figure d) Fused image based on Weighted average Method

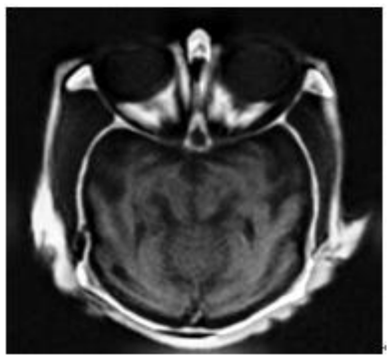


Figure e) Fused image based on Wavelet Transform

Figure 6: Input images and fused image results

This paper uses MRI and CT as input images. Fusion operation is performed with these images using Weighted average method and Wavelet Transform method.

IV. QUALITY EVALUATION

In this paper, we use four parameters to assess the fusion quality. These parameters are peak-to-peak signal-to-noise ratio (PSNR), information entropy

A) Peak-to-peak signal-to-noise ratio (PSNR)

This method to evaluate the effect of the fused images. Suppose *R* is the source image (standard reference image) and *F* is the fused image; the root mean square error (RMSE) [6] is defined as follows:

$$RMSE = \sqrt{\frac{\sum\sum [R(i,j)-F(i,j)]2}{M \; X \; N}} \qquad 4.1$$

The RMSE is used to measure the difference between the source image and the fused image; the smaller the value of RMSE and the smaller the difference, the better the fusion Performance.

Peak-to-peak signal-to-noise ratio is defined as follows:

$$PSNR = 10 \; X \; \ln (f_{max} \; X \; f_{max} / RMSE^2) \qquad 4.2$$

Where ln is the natural logarithm operation and f_{max} is the maximum gray value of the pixels in the fused image.

Higher the value of PSNR, the better the fusion performance.

B) Information Entropy

Information entropy is an important factor to reflect the information abundance that an image contains. The bigger of the fusion image entropy is, the more abundant of information the fusion image contains. Information entropy can be used for comparing the difference of image details. Entropy is defined as follows:

$$H = -\sum_{i=0}^{255} P_i \log_2 P_i$$

Where P_i is the probability of pixel gray value i.

THE RESULT OF THE FUSION METHOD

	Fusion Method	PSNR	Entropy
1)	Weighted Average Method	68.44	5.7937
2)	Wavelet transform	72.11	6.7542

V. CONCLUSION

The experiment results show that the wavelet transform is a powerful method for fusion of images. The primitive fusion schemes perform the fusion right on the source images, which often have serious side effects such as reducing the contrast. This fusion algorithm, based on wavelet transform, is an effective approach in image fusion area.

Our application is intended to be useful for physicians who need to fusion multi-modality images for support in diagnosis.

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