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A Comparative Analysis of CT and MRI Image Fusion using Wavelet and Framelet Transform

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ABSTRACT – Medical image fusion has been used to derive useful information from multimodality medical image data. 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 aims to demonstrate the application of wavelet transformation and framelet transformation to multimodality medical image fusion. This work covers the selection of wavelet and framelet function, the use of wavelet based and framelet based fusion algorithms on medical image fusion of CT and MRI, implementation of fusion rules and the fusion image quality evaluation. The fusion performance of both wavelet and framelet transform is evaluated on the basis of the root mean square error (RMSE) and peak signal to noise ratio (PSNR). So here we are using wavelet and framelet transform for fusing images, the fusion performance of both transforms are compared and evaluated.

Index terms - Medical image fusion, Multimodality images, Wavelet transform, Framelet transform, Fusion rules.

I. INTRODUCTION

The objective of image fusion is to combine information from multiple images of the same scene. The result of image fusion is a new image which is more suitable for human and machine perception or further image-processing tasks such as segmentation, feature extraction and object recognition. Multiresolution Image fusion is the process of combining relevant information from two or more images into a single image. The resulting image will be more informative than any of the input images. Several situations in image processing require both high spatial and high spectral information in a single image. However, the instruments are not capable of providing such information either by design or because of observational constraints. One possible solution for this is data fusion. In medical image fusion doctors can combine the CT and MRI medical images of a patient with a tumor to make a more accurate diagnosis, but it is inconvenient and tedious to finish this job. And more importantly, using the same images, doctors with different experiences make inconsistent decisions. Thus, it is necessary to develop the efficiently automatic image fusion system to decrease doctor's workload and improve the consistence of diagnosis. The simplest way of image fusion is to take the average of the two images pixel by pixel. However, this method usually leads to undesirable side effect such as reduced contrast. Due to the multiresolution transform can contribute a good mathematical model of human visual system and can provide information on the contrast changes, the multiresolution techniques have then attracted more and more interest in image fusion. In this paper, a novel approach for the fusion of CT and MRI images based on wavelet transform and framelet transform has been presented. Different fusion rules are then performed on the coefficients of low and high frequency portions. The registered CT and MRI images of the same people and same spatial parts have been used for the analysis.

II. IMAGE FUSION BASED ON WAVELET TRANSFORM

A. Wavelet Transform

The wavelet transform, originally developed in the mid 80's, is a signal analysis tool that provides a multi-resolution decomposition of an image in a biorthogonal basis and results in a non-redundant image representation. This basis is called wavelets, and they are functions generated from one single function, called mother wavelet, by dilations and translations. The wavelets-based approach is appropriate for performing fusion tasks for the following reasons:

1) In recent years, multiscale representation of a signal and have established that multiscale information can be useful in a number of image processing applications including the image fusion.
2) The discrete wavelets transform (DWT) allows the image decomposition in different kinds of coefficients preserving the image information.
3) Such coefficients coming from different images can be appropriately combined to obtain new coefficients, so that the information in the original images is collected appropriately.

4) Once the coefficients are merged, the final fused image is achieved through the inverse discrete wavelets transform (IDWT), where the information in the merged coefficients is also preserved.

B. Wavelet Transform Implementation for Multiresolution Decomposition Images

The discrete wavelet transform (DWT), which applies a two- channel filter bank iteratively to the low pass band. The wavelet representation then consists of the low pass band at the lowest resolution and the high pass bands obtained at each step. The DWT is a spatial-frequency decomposition that provides a flexible multiresolution analysis of an image. The wavelet transform coefficient can be obtained by an inner calculation:

$$c_{m,n}=(f, \Psi_{m,n}) = \int \Psi_{m,n}(t)\, f(t)\, dt \qquad (1)$$

In order to develop a multiresolution analysis, a scaling function □ is needed.

$$\square_{m,n}(t) = 2^{-m/2} \square\, [2^{-m}t-n] \qquad (2)$$

The 2-D wavelet analysis operation consists in filtering and down-sampling horizontally using the 1-D low pass filter L and high pass filter H to each row in the image I (x; y), producing the coefficient matrices $I_L(x;\ y)$ and $I_H\ (x;\ y)$. Vertically filtering and down-sampling follows, using the low pass and high pass filters L and H to each column in $I_L(x;\ y)$ and $I_H\ (x;\ y)$ and produces four subimages $I_{LL}(x;\ y)$, $I_{LH}\ (x;\ y)$, $I_{HL}(x;\ y)$ and $I_{HH}\ (x;\ y)$ for one level of decomposition. $I_{LL}(x;\ y)$ is a smooth subimage as a smoothed and subsampled version of the original image I (x; y), i.e. it represents the coarse approximation of I (x; y). $I_{LH}\ (x;\ y)$, $I_{HL}(x;\ y)$ and $I_{HH}\ (x;\ y)$ are detail subimages, which represent the horizontal, vertical and diagonal directions of the image I (x; y).

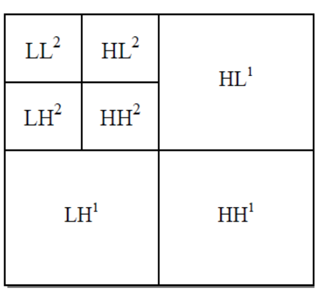

Fig.1 Image Subbands for two level decomposition

C. Wavelet Transform for Fusing Images

In general, the basic idea of image fusion based on wavelet transform is to perform a multiresolution decomposition on each source image; the coefficients of both the low-frequency band and high-frequency bands are then performed with a certain fusion rule.

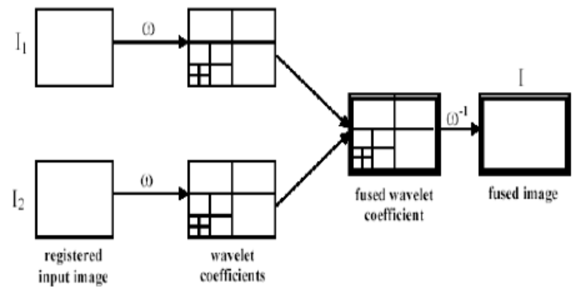

Fig.2 The scheme for Image Fusion using wavelet Transform

This simple scheme just selects the largest absolute wavelet coefficient at each location from the input images as the coefficient at the location in the fused image. After that, the fused image is obtained by performing the inverse DWT (IDWT) for the corresponding combined wavelet coefficients. The detailed fusion steps based on wavelet transform can be summarized below:

Step 1. The images to be fused must be assured that the corresponding pixels are aligned.
Step 2. These images are decomposed into wavelet transformed images. The transformed images with K-level decomposition will include one low-frequency portion (low low band) and 3K high-frequency portions (low-high bands, high-low bands, and high-high bands).
Step 3. The transform coefficients of different portions or bands are performed with a certain fusion rule.
Step 4. The fused image is constructed by performing an inverse wavelet transform based on the combined transform coefficients from Step 3.

III. IMAGE FUSION BASED ON FRAMELET TRANSFORM

Though standard DWT is a powerful tool for analysis and processing of many real-world signals and images, it suffers from three major disadvantages, Shift- sensitivity, Poor directionality and Lack of phase information. These disadvantages severely restrict its scope for certain signal and image processing applications.

Frames, or over complete expansions, have a variety of attractive features. With frames, better time-frequency localization can be achieved than is possible with bases. Some wavelet frames can be shift invariant, while wavelet bases cannot be. Frames provide more degrees of freedom to carry out design.

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A. Framelet Transform

Framelet are very similar to wavelets but have some important differences. In particular, whereas wavelets have an associated scaling function □(t) and wavelet function Ψ(t), framelets have one scaling function □(t) and two wavelet functions Ψ1(t) and Ψ2(t). The scaling function □(t) and the wavelets Ψ1(t) and Ψ2(t) are defined by the low-pass (scaling) filter h0(n) and the two high-pass (wavelet) filters h1(n) and h2(n).

The filters $h_i(n)$ and $h_i(-n)$ should satisfy the perfect reconstruction (PR) conditions. From basic multirate identities, the PR conditions are the following:

$$H_0(z).H_0(1/z)+H_1(z).H_1(1/z)+H_2(z).H_2(1/z)=2 \quad (3)$$

And

$$H_0(-z).H_0(1/z)+H_1(-z).H_1(1/z)+H_2(-z).H_2(1/z) \quad (4)$$

B. Framelet Transform Implementation

The framelet transform is implemented on discrete-time signals using the over sampled analysis and synthesis filter bank. The analysis filter bank consists of three analysis filters- one low pass filter denoted by $h_0(n)$ and two distinct high pass filters denoted by $h_1(n)$ and $h_2(n)$. As the input signal X(N) travels through the system, the analysis filter bank decomposes it into three sub bands each of which is then down-sampled by 2. From this process $X_L(N/2)$, $X_{H1}(N/2)$ and $X_{H2}(N/2)$ are generated, which represent the low frequency (or coarse) subband and the two high frequency (or detail) sub bands, respectively.

The up sampled signals are filtered by the corresponding synthesis low pass $h_0{*}(n)$ and two high pass $h_1{*}(n)$ and $h_2{*}(n)$ filters and then added to reconstruct the original signal. Note that the filters in the synthesis stage, are not necessary the same as those in the analysis stage. For an orthogonal filter bank, $h_i{*}(n)$ are just the time reversals of $h_i(n)$.

LL	LH_1	LH_2
H_1L	H_1H_1	H_1H_2
H_2L	H_2H_1	H_2H_2

Fig.3 Image Subbands for single level decomposition

C. Framelet Transform for Fusing Images

Both the CT and MRI images are decomposed using framelet transform to create different high and low frequency components. The high frequency component contains image details such as noise, edges and details. On the other hand, the low frequency components contain basic image information. The coefficients of the low frequency component and the high frequency components are then performed with a certain fusion rule. This selects the largest absolute framelet coefficient at each location from the input images as the coefficient at the location in the fused image. To reconstruct the fused image from the discrete framelet transformed signal, inverse fast discrete framelet transform should be used. The inverse transformation matrix is the transpose of the transformation matrix as the transform is orthogonal. To construct the inverse framelet transform reconstruction matrix should be formed from transformation matrix. Reconstruction of the input matrix is by multiplying the reconstruction matrix with the input matrix and by the transpose of the reconstruction matrix.

IV. PERFORMANCE EVALUATION

The performance evaluation can be measured using Root Mean Square Error (RMSE) and Peak Signal to Noise Ratio (PSNR) between the reconstructed image and the original image for every fusion performed. Though standard DWT is a powerful tool for analysis and processing of many images, it suffers from, Shift- sensitivity, Poor directionality and Lack of phase information. This will restrict its scope for signal and image processing. Redundancy is an important property of framelet transform; which is widely used in data denoising and objects identification. The noise in the fused image will be reduced than using wavelet transform. On analyzing the performance of the wavelet and framelet transform, for fusing images, smallest RMSE and highest PSNR should achieve. Framelet transform will provide smallest RMSE and highest PSNR than wavelet transform.

V. CONCLUSION

We have used the wavelet transform, framelet transform and various fusion rules to fuse CT and MRI images. This method gives results in terms of smaller RMSE and higher PSNR values. Among all the fusion rules, the maximum fusion rule performs better as it achieved least MSE and highest PSNR values. Though wavelet transform gives encouraging result, better performance is obtained in framelet transform.

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