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Design and Implementation of Pixel Level Medical Image Fusion

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Abstract- Medical image fusion has become a common term used with in medical diagnostics and treatment. Image fusion means the combining of two images into a single image that has the maximum information content without producing details that are non-existent in the given images. The term is used when multiple patient images are registered and overlaid or merged to provide additional information. Fused images may be created by combining information from multiple modalities, such as magnetic resonance image (MRI), computed tomography (CT). For example, CT images are used to determine hard bone information while MRI images are typically used to visualize soft tissue information.

In this paper, discrete wavelet transform (DWT) based technique for medical image fusion is presented. Firstly, the medical images to be fused are decomposed by the DWT. DWT coefficients from two input images are fused pixel-by pixel by choosing the average of the approximation coefficients. Then an inverse DWT is performed to obtain the fused image.

For the same images we apply Discrete Multi Wavelet Transform (DMWT). Then we evaluate the fused image for various parameters like peak signal to noise ratio (PSNR), entropy, standard deviation (std dev) and quality for both the methods. The results indicate that multi-wavelet transform is superior as compare to wavelet transform.

Keywords: Pixel level image fusion, wavelet transform, multi wavelet transform, PSNR, image quality evaluation, multi-wavelet transform, GUI

INTRODUCTION

Image Fusion is a process of combining the relevant information from a set of images, into a single image, such that the resultant fused image will be more informative and complete than any of the input images. Therefore the new image generated should contain a more accurate description of the scene than any of the individual source images and is more suitable for human visual and machine perception or further image processing and analysis tasks. For example, CT and MR images may be fused as an aid to medical diagnosis [3]. IR and visible images may be fused as an aid to pilots landing in poor weather condition or microwave and visible images may be fused to detect weapons. The fusion process must satisfy the following requirements such as it should preserve all relevant information in the fused image, should reduce noise and should minimize any artifacts in the fused image. There are two approaches to image fusion, namely Direct Fusion and Multi resolution fusion [3]. In Direct fusion, the pixel values from the source images are summed up and taken average to form the pixel of the composite image at that location [1]. Multi resolution fusion uses pyramid or wavelet transform for representing the source image at multi scale. In satellite imaging, two types of images are available. The panchromatic image acquired by satellites is transmitted with the maximum resolution available and the multispectral data are transmitted with coarser resolution. This will usually be two or four times lower. At the receiver station, the panchromatic image is merged with the multispectral data to convey more information. Because of the characteristic of image fusion technology, it has recently been widely applied in various fields such as auto target recognition, computer vision, Concealed weapon detection and medical image processing etc. The advantages of image fusion are improving reliability and capability.

Pixel level fusion using curvelet transform for medical image fusion is discussed in this paper. The paper is organized as follows. Section II and Section III explains the image fusion system based on wavelet and multi wavelet transforms methods respectively. Section IV deals with various performance evaluation parameters of pixel level image fusion. Section V gives brief introduction about GUI. Section VI included experimental results.

WAVELET TRANSFORM BASED IMAGE FUSION

Wavelet transform is usually used in image fusion. The Discrete Wavelet Transform (DWT) of image signals produces a non-redundant image representation, which provides better spatial and spectral localization of image formation, compared with other multi scale representations such as Gaussian and Laplacian pyramid.

For one level of decomposition there will be four frequency bands, these are Low-Low(LL), Low-High(LH), High-Low(HL), High-High(HH).

In each level, there are three detail components of high-frequency and approximated one of low-frequency. The detail components include LH (horizontal information), HL (vertical information) and HH (diagonal information). The approximated component LL describes picture figure. In the first level, the frequency components are LH1, HL1, HH1 and LL1 respectively. The next level, LL1 is decomposed into LH2, HL2, HH2 and LL2 as shown in figure 2.

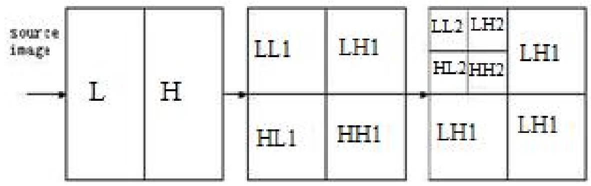


Fig. 2 Wavelet Transform decomposition of 1st and 2nd level

Where H- High frequency band, L- Low frequency band and 1, 2, 3- Decomposition level.

Fig. 3 shows the structure of 2-dimensional Discrete Wavelet Transform with 3 decomposition levels. The next level decomposition is just applied to the LL band of the current decomposition stage, which forms a recursive decomposition step.

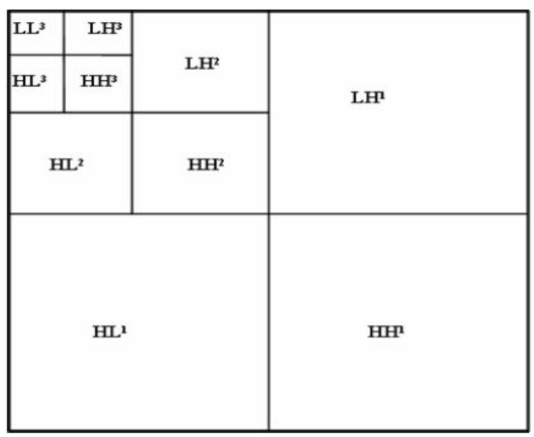


Fig. 3 Structure of 2-D DWT with 3 decomposition level

Therefore, N-level decomposition will finally have 3N+1 different frequency bands, which include 3N high frequency bands and just one LL frequency band. The frequency bands in higher decomposition levels will have smaller size [3].

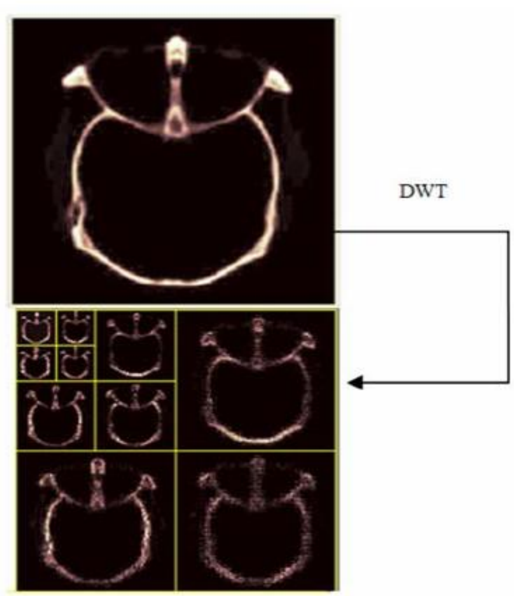


Fig. 4 wavelet decomposition at level 3 example of CT Image

Here is the example of the integration of two images and the fusion of multiple images can be inferred. A and B are the original images needed to be fused. F is the image of fusion result. The general process [2] is as follows and shown in fig. 5.

Step 1. Carry Discrete Wavelet Transform on each source images to create wavelet decomposition coefficient.
Step 2. Fuse each decomposition coefficient individually by using different fusion operator to different frequency component and finally get a wavelet pyramid after the fusion processing.
Step 3. Carry Inverse Discrete Wavelet Transform on the wavelet pyramid, which means to reconstruct the image, while the image reconstructed is the fused image F.

Wavelet transform has the disadvantage that it can not have orthogonality, symmetry, smoothness, vanishing moments that are very important for image processing.

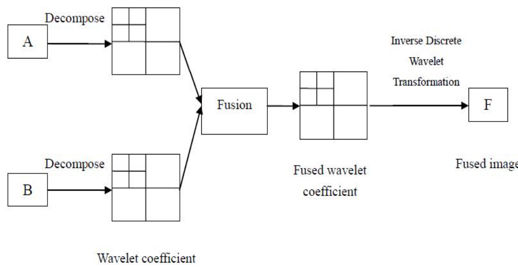
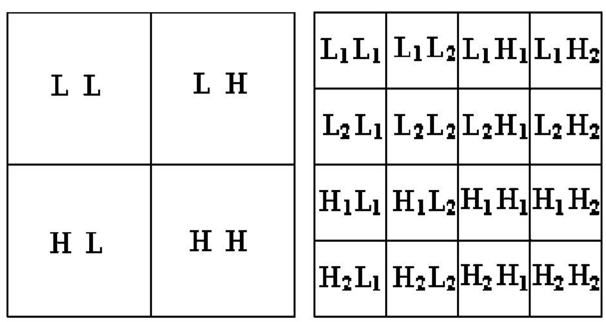


Fig. 5 The Process of Wavelet based image fusion

DISCRETE MULTI WAVELET TRANSFORM BASED IMAGE FUSION

Multi-wavelets is an expansion of traditional wavelet and has more advantages [5]. It is most important that a multi-wavelets system can simultaneously have these characteristics that are preserving length (orthogonality), good performance at the boundaries because of linear-phase symmetry, and a high order of approximation also named vanishing moments. Thus, discrete multi-wavelets transform offers the possibility of superior performance for image fusion, compared with traditional scalar wavelets.



(a) (b

Fig. 6 Image subbands after a single-level decomposition, for (a) scalarwavelets and (b) multiwavelets.

During a single level of decomposition using a scalar wavelet transform, the 2-D image data is replaced with four blocks corresponding to the subbands representing either lowpass or highpass filtering in both dimensions. These subbands are illustrated in Fig. 8(a). The multiwavelet single level decomposition for subbands are shown in Fig. 8(b). In practice, more than one decomposition is performed on the image data.
Suppose the source images are A and B, the fused image is F, and the greatest multi wavelet decomposition scale is L, the steps of multi wavelet fusion algorithm are given below [5].

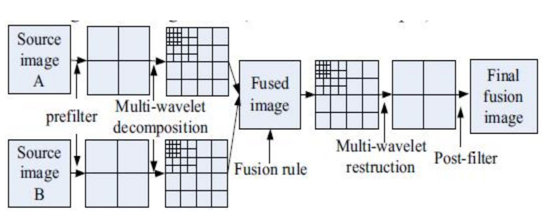


Fig. 7 Image fusion scheme based on DMWT

Step1. The source images A and B are Pre-filtered to obtain pre-filtered image preA and preB.
Step 2. The L scale multi-wavelet decomposition of the pre-filtered images preA and preB is carried out Separately.
Step 3. Fuse each decomposition coefficient individually by using different fusion operator to different frequency component and finally get a multi wavelet pyramid after the fusion processing.

THE EVALUATION OF IMAGE FUSION

The evaluation parameters used in this paper are peak signal to noise ratio (PSNR), entropy, standard deviation and quality of the fused image [4].

- The root mean square error (RMSE) between the reference image R and fused image F is given by following formula, where, M and N indicate the size of the image is M×N, F(i, j) and R(i, j) indicate the gray value of the pixel which is in row i and in the column j of the image. The smaller the value of RMSE, the better the fusion effect is.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j}^{N}[R(i,j) - F(i,j)]^2}{M \times N}}$$

- The peak signal to noise ratio (PSNR) between the reference image R and thee fused image F is given by [4]

$$PSNR = 10\lg\frac{255^2 MN}{\sum_{i=1}^{M}\sum_{j=1}^{N}[F(i,j) - R(i,j)]^2} = 10\lg\frac{255^2}{RMSE^2}$$

Where M and N indicate the size of the image is MxN, F(i, j) and R(i, j) indicate the gray value of the pixel which is in row i and in the column j of the image. The higher the value of PSNR the better the fusion effect is.

- Quality index of the reference image R and the fused image F is given by [4]

$$Q = \frac{4\,\sigma_{ab}\,ab}{(a^2 + b^2)(\sigma_a{}^2 + \sigma_b{}^2)}$$

The maximum value Q =1 is achieved when two images are identical, where a and b are mean of images, σ_{ab} be covariance of R and F, $\sigma_a{}^2$, $\sigma_b{}^2$ be the variance of image R and F.

- Entropy defines the average amount of information of the image

$$H = -\sum_{i=1}^{G} P(i)\log_2(P(d_i))$$

Where G is the number of possible gray levels, P(di) is probability of occurrence of particular gray level di. [4]

- Standard Deviation (STD DEV) of gray image reflects clarity and contrast, the greater the value is, the more clear and contrast of the image; on the other hand, the smaller the image contrast is, the more affected by noise. The standard deviation [5] is:

$$\sigma_x = \sqrt{\frac{1}{MN-1}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j) - \bar{x})}$$

Where M×N is size of image x, x(i, j) is the gray value of pixel (i, j) and $\bar{x}$ denote the mean of x given by:

$$\bar{x} = \frac{1}{MN-1}\sum_{i=1}^{M}\sum_{j=1}^{N} x(i,j)$$

GRAPHIC USER INTERFACE

A Graphical User Interface (GUI) is a platform for application testing and analysis which consists of user interface controls like push buttons, edit boxes, radio buttons, menus and a variety of objects for graphics programming. MATLAB has advanced capabilities and graphical interface tools for real-time application development. Image fusion requires graphical tools for better image perception and performance evaluation of the fusion rules used.

In order to achieve a GUI with good performance, the design steps are as follows:

- Analysis the main function that the interface requires, determine the design task.
- Draw an outline sketch of the interface.
- According to the sketch, design static interface firstly and check it carefully.
- Write the dynamic program through implementing the corresponding callback functions of the objects on the interface [1].

It should be noted that design steps may be need to be modified several times so as to get a satisfactory interface finally.

EXPERIMENTAL RESULT

Here we take one CT image and one Magnetic resonance image and we will perform discrete wavelet transform to fuse them so that fused image will be more informative than the individual image for clinical purpose. After that we will apply discrete multi wavelet transform for the same type of images.

Fig. 8 shows the image fusion evaluation menu. Further in fig. 9 we load the CT and MRI images respectively. Fig. 10 shows the image fusion based on DWT with various parameters like PSNR, Entropy, Standard deviation and Quality.

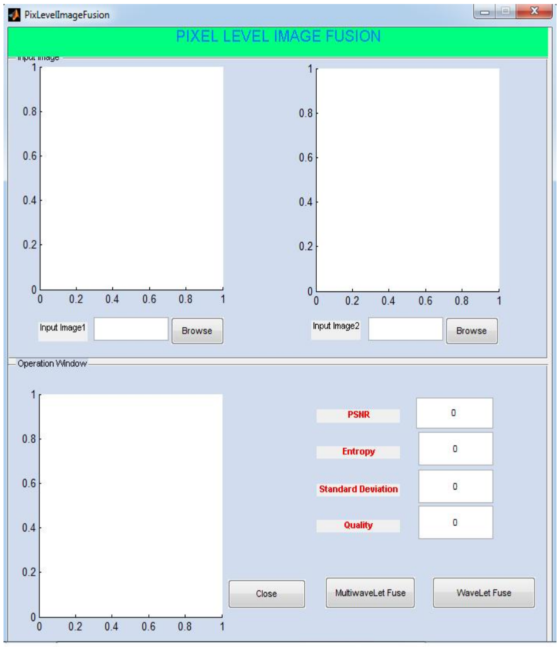


Fig. 8 Image fusion evaluation menu

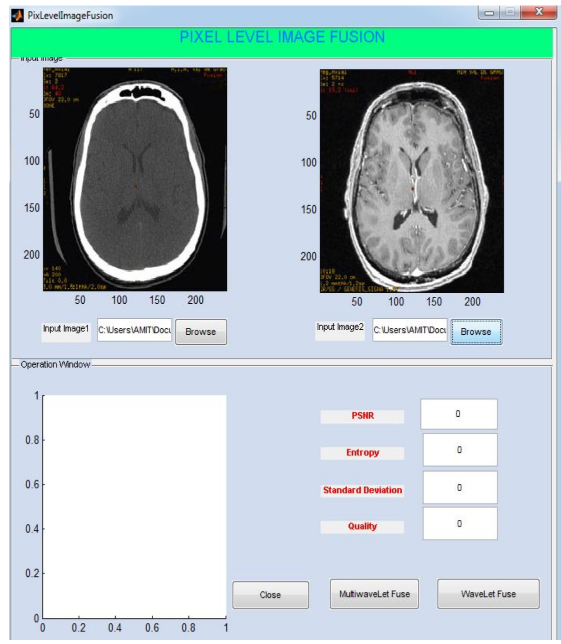


Fig 9 Loading CT and MRI as input image 1 and input image 2 respectively

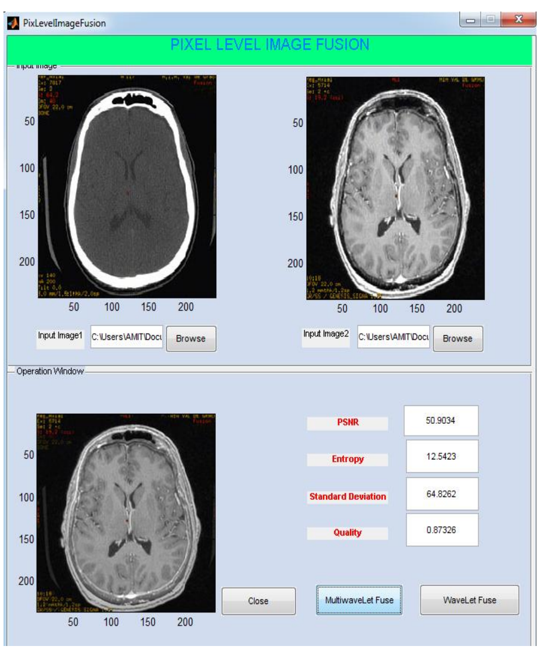


Fig. 10 Image fusion scheme based on DWT

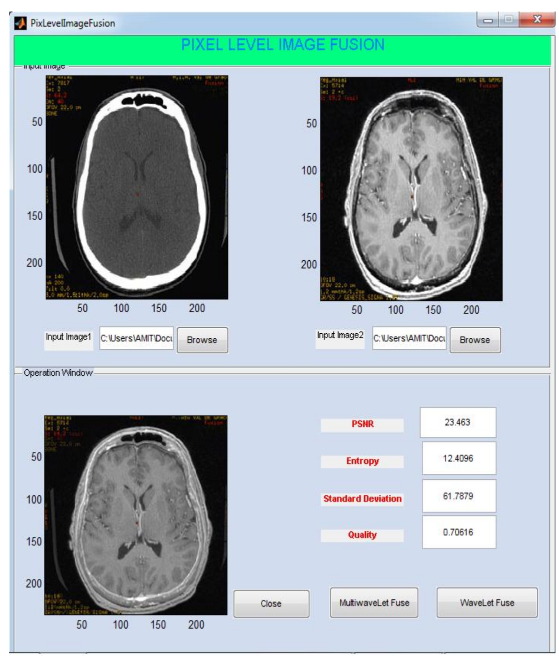


Fig. 11 Image fusion scheme based on DMWT

DMWT method provides higher value of quality, standard deviation, entropy as well as PSNR as shown in fig. 11. Higher values of these parameters indicate the better result of image fusion.

CONCLUSION

We have explained discrete wavelet transform and multi wavelet transform. In this paper, we have taken CT image and Magnetic resonance images for fusion. We have applied pixel level image fusion methods like traditional discrete wavelet transform and multi wavelet transform to fuse them so that fused image will be more informative than the individual image for clinical purpose. We found that results of multi wavelet transform are superior than the wavelet transform method in terms of PSNR, Entropy, Standard Deviation and image quality.

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