Image Fusion and Secure Transmission of Medical Images

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Abstract— **Medical image fusion helps improve diagnosis by combining complementary data from different imaging modalities such as CT (Computed Tomography), MRI (Magnetic Resonance Imaging), PET (Positron Emission Tomography) etc. The resulting image will be more informative and it also helps to reduce the storage space requirement to a greater extent. Several techniques for image fusion have been developed. But distortion of fine details remains important concerns. In this paper a two step medical image fusion scheme is presented. Various individual multi-scale fusion methods are performed in the first step. In the second step these individual fused images are combined with local structural similarity measures used as weights. It is observed that in this way a superior quality fused image can be obtained. This paper also deals with the secure transmission of the images. Least significant bit insertion based steganography is used here to achieve the secure transmission.**

Index Terms— **DWT, Image fusion, LSB, SSIM**

I. INTRODUCTION

Fusion is the process of combining salient information from multiple images of the same scene. The image may have different spatial and spectral characteristics, obtained at different times or may be captured from different sensors. Fused image will retain the most desirable information and characteristics of each input image. Many fusion applications have appeared in medical imaging like simultaneous evaluation of CT, MRI, and/or PET images. CT scan emphasizes dense structures such as bones, MRI scan shows soft tissue anatomical details, while PET and SPECT (Single-photon emission computed tomography) images visualize activity in the body. Instead of looking at different types of images separately physicians can inspect the fused image which combines useful information from multiple scanners into one image. Image fusion can take place either in transform domain or in spatial domain. In transform domain, the input images are first transformed using wavelet decomposition or pyramid decomposition to exploit the information at different scales or multi-resolutions (MR) whereas in spatial domain the pixel values are directly incorporated in fusion process.

The most commonly used approach is to perform the fusion in the multi-scale transform domain. The advantage of this method is that different fusion rules can be applied to coefficients at various levels of the transformation. After fusion the inverse transform is applied to obtain the fused image. In this paper, two widely used multi-scale transformations i.e., Laplacian pyramid and Discrete Wavelet transform are used for fusing the medical images. Fusion can be performed for either monomodality or multimodality images. In this paper two MRI images with different information content are chosen.

Combination of individual results is expected to improve the quality. The problems related to the quality of one multi-scale medical image fusion technique can be compensated by the advantage of another. Keeping this in mind, we propose a novel ensemble method based on weighted sum of individual results. The output of the proposed scheme gives better quality images compared to the individual techniques.

Due to recent expansions of information technology, the distribution of medical images among hospitals has become a common trend. Medical images are often circulated for specific requirements such as for teleconferences and

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interdisciplinary exchanges among medical personnel. Thus it is essential to ensure the protection of image information. A digital data hiding technique can provide this needed protection by embedding medical information data into other data (called the host or cover data). In this paper LSB based technique is used to provide data security.

II. LITERATURE REVIEW

Multimodal medical image fusion using wavelet transform with spatial frequency method for MRI-PET images has been proposed in [1]. Spatial frequency is used to measure the clarity of image blocks and overall activity level in an image. This method was designed for joint analysis of medical images from various imaging modalities and also for efficient color image fusion.

In paper [2] author proposed a fusion technique based on DWT. Here in the first step the medical images to be fused are decomposed using DWT. Secondly by considering the characteristics of human visual system (HVS) and the physical meaning of wavelet coefficients, different fusion rules are applied on low frequency and high frequency bands separately followed by a window based consistency verification. Finally, the inverse DWT is applied to obtain the fused image. They have compared the proposed method with some of the existing methods and it has shown noticeable improvements in quality analysis.

An approach to implement image fusion algorithm using Laplacian Pyramid is presented in [3]. They have implemented a pattern selective approach to image fusion. Pyramid decomposition is performed on each source image and finally reconstructed the fused image by performing inverse pyramid transform. The aim of image fusion apart from reducing the storage space requirement, is to create new images that are more suitable for the purposes of machine/human perception, and for further image processing tasks such as segmentation ,classification etc.

Shift dependency effects on multi resolution based image fusion performance are explained in [4]. Majority multi-resolution schemes are not shift invariant because of the subsampling process used in the calculations. This affects the combination of the coefficients in the fusion rule. They have shown that shift dependency affects the quality of fused image. Shift invariant schemes are redundant. Non redundant fusion schemes can be preferred to achieve good computational performance.

Objective methods for assessing perceptual image quality, attempted to quantify the visibility of differences between a reference image and a distorted image. Another method for quality assessment which is based on the degradation of structural information is presented in [5]. They have presented an SSIM index and showed that it gives better performance when compared with other methods in accounting for their experimental analysis of subjective quality of JPEG2000 and 344 JPEG compressed images.

A robust image steganography based on LSB insertion and encryption is presented in [6]. Steganography is the term which denotes the process of concealing the existence of information. Attackers use the method called steganalysis to determine if images have hidden data and to recover that data. They have implemented a means to encrypt the user's data using the public key RSA algorithm.

III. PROPOSED METHOD

In this proposed method a two step fusion scheme is presented. In the first step the two multi-scale fusion schemes i.e., DWT based fusion and Laplacian pyramid based fusion are applied separately on the input images to obtain the fused images. These images are treated as the intermediate stage results. In the second step these intermediate results are combined using weighted average, with local structural similarity measures used as weights [7]. Block diagram representation of the proposed scheme is shown in Fig 1. By combining the fusion results of the two fusion methods mentioned, it is observed that a superior quality fused image is obtained. Two quality measures including PSNR (Peak Signal to Noise Ratio) and RMSE (Root Mean Square Error) are performed over the fused images to verify the results. The proposed method has shown noticeable improvements in the quality evaluation.

To provide secured transmission of the medical images, Least-Significant-Bit (LSB) steganographic data embedding is used in this project. The advantages of this method are that it is simple to understand, easy to implement, and it produces stego-image that is almost similar to cover image and its visual variations cannot be judged by naked eyes.

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The various steps involved in this method are listed below;

1) Preprocessing of source images
2) DWT and Laplacian pyramid based fusion
3)Obtain the fused image by applying corresponding inverse transforms
4) Combine the intermediate fused results

A. Pre-processing of source images

Regardless of the method used for fusion, the source images to be fused should be perfectly registered and should be made equal in size. Image scaling is the process of resizing a digital image. In this project the built in function available in MATLAB R2012a for image resizing is used. The interpolation algorithm used is bilinear interpolation. Bilinear interpolation is used for interpolating functions of two variables on a regular two dimensional grid. Once the sizes of source images are made equal, image registration should be performed. This is essential for good fusion quality. In this paper images are registered using automatic multi-modal image registration functions in MATLAB R2012a.

B. DWT based Image Fusion

The wavelet transform is a mathematical tool that can be used to decompose two dimensional (2-D) signals such as 2-D gray-scale image signals into various resolution levels for multi-resolution analysis. The image is decomposed with each level corresponding to a coarser resolution or lower frequency band, and higher frequency bands. The two main groups of transforms are continuous and discrete. Of particular interest is DWT, which applies a two-channel filter bank (with down sampling) iteratively to the low-pass band (initially the original image).The wavelet representation then consist of the low-pass band at the lowest resolution and the high-pass obtained at each step. DWT is invertible and non-redundant.

In a two-dimensional DWT, a 1-D DWT is performed on the rows and then on columns of the data by separately filtering and down sampling. It provides one set of approximation coefficients 'I_a' and three sets of detail coefficients as shown in Fig 2, where 'I_b', 'I_c', 'I_d' denote the horizontal, vertical and diagonal directions of the image 'I', respectively and represents downsampling operation by a specified factor. Low pass and high pass filters are represented by 'h' and 'g' respectively.

The basic idea of image fusion based on wavelet transform is to perform a multi-resolution decomposition of each source image. Obtain the coefficients of both low frequency band and high frequency band and then perform certain fusion rules. The source images are decomposed in rows and columns by low-pass (L) and high-pass (H) filtering and subsequent down sampling at each level to get approximation (LL) and detail (LH, HL and HH) coefficients [8]. The IDWT (Inverse Discrete Wavelet Transform) is applied on fused coefficients, to obtain final fused image. From the wavelet toolbox available in MATLAB, '*dwt2*' is used to perform the wavelet decomposition of the source images. Appropriate wavelet can be chosen from the wavelet families provided by the toolbox. Since wavelet family of Symlets have better symmetry than Daubechies wavelet family, Symlets wavelets are more suitable for image processing.

C. Laplacian Pyramid based Image Fusion

One effective structure used to describe image is the image pyramid. The basic principle of this method is to decompose the original image into sub images with various spatial resolutions through some mathematical operations. Laplacian pyramid is derived from Gaussian pyramid. It is a multi-scale representation obtained through a recursive low-pass filtering and downsampling operation. The difference between the adjacent two images is to be found in order to reduce larger number of redundant information from Gaussian pyramid and get the band-pass filtered images, which is the Laplacian pyramid.

D. Combining Stage

The final stage of the proposed method is to combine the fused images of each fusion method using local structural similarity measures that are used as weights. Mathematically,

$$W_m = Q_{SSIM}(F_m)^k \quad (1)$$

Here $'k'$ is some small positive value, $'W_m'$ is the weightage given for the m^{th} fusion scheme and $'F_m'$ is the fused image produced by m^{th} scheme. Some small positive value can be chosen as $'k'$ to boost the weightage.

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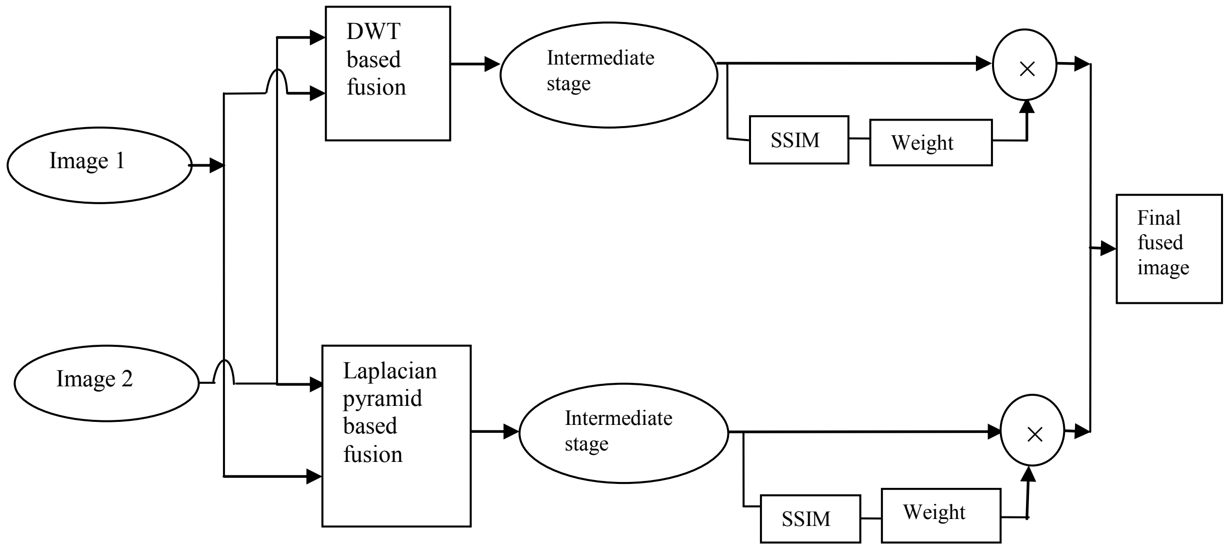

Fig 1. Block diagram of the proposed fusion scheme

Algorithm:

For each neighborhood traversed by a sliding window compute the mean $'\mu'$, standard deviation $'\sigma'$, variance $'\sigma^2'$, covariance $'\sigma_{i,j}^2'$ of source images.

$$S = \frac{(2\mu_i\mu_f + C_1)(2\sigma_{i,f} + C_2)}{(\mu_i^2\mu_f^2 + C_1)(\sigma_i^2 + \sigma_f^2 + C_2)} \quad (2)$$

$$Q_{SSIM,i} = \frac{1}{R.C}\sum_{p=1}^{R}\sum_{q=1}^{C} S(p,q) \quad (3)$$

Where $'R'$, $'C'$ represents number of rows and columns of images. C_1 and C_2 are constants .

E. Steganography Stage

Steganography provides secrecy of images or text in order to prevent them from attackers. Steganography hide the message image or text in a cover image and changes its properties. It provides secret communication so that intended hacker or attacker will not be able to detect the existence of message. In this paper Least-Significant-Bit (LSB) data embedding method is performed.

There are two types of digital images, (i) 8 bit images and (ii) 24 bit images. Steganography applications

that hide message information in cover images generally use a variation of least significant bit (LSB) embedding method. The data is hidden in the LSB of each byte in the cover image. Each unique numerical pixel value corresponds to a color. Decreasing or increasing the value by changing the LSB does not affect the appearance of the image. So the cover image and the resultant stego image look almost same. One bit of information can be hidden in 8 bit images. Each pixel corresponds to 256 colors and the selected pixels indicate certain colors on the screen.

Suppose we are given with two identical images, if the LSB of the pixels in one image are changed, then to the human eye the two images still look identical. This is because the human eye is not sensitive enough to observe the changes in color between pixels that are different by 1 unit. Steganography applications use LSB embedding because attackers do not notice anything suspicious or odd about an image if its pixel's least significant bits are modified.

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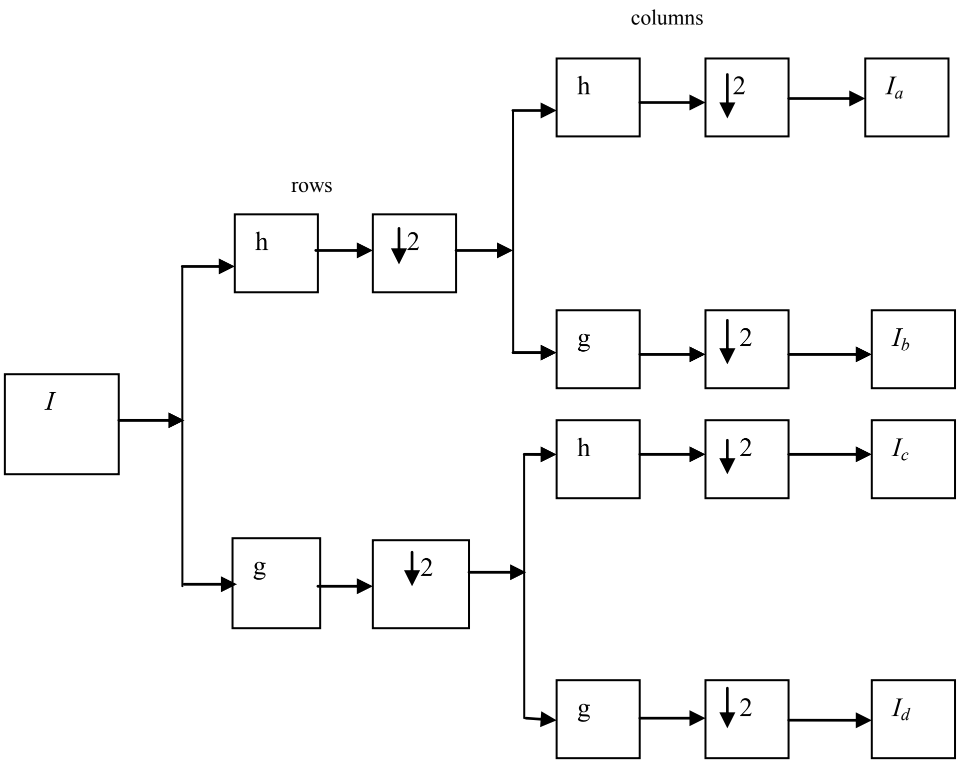


Fig 2. Structure of 2-D DWT

IV. PERFORMANCE EVALUATION

The various quality measures which are used to provide an accurate evaluation of fusion quality are explained below. Here the fused image is compared with both input images. The obtained quality measure for each case is combined using equation (4). That is,

$$\bar{Q}(I_f, I_1, I_2) = \frac{Q(I_f, I_1) + Q(I_f, I_2)}{2} \quad (4)$$

Here I_f, I_1, I_2 represents fused image, first input image and second input image respectively.

A. PSNR (Peak Signal to Noise Ratio)

PSNR is the ratio of the maximum signal power and noise power. High value of PSNR indicates greater quality of image. PSNR for reference image $'R'$ and fused image $'F'$ is calculated on the basis of MSE (mean square error).

$$PSNR(R, F) = 10 log_{10} \frac{N^2}{MSE(R, F)} \quad (5)$$

where $'\mathrm{N}'$ represents maximum number of pixel levels in an image which takes value 255 for 8 bit gray scale images.

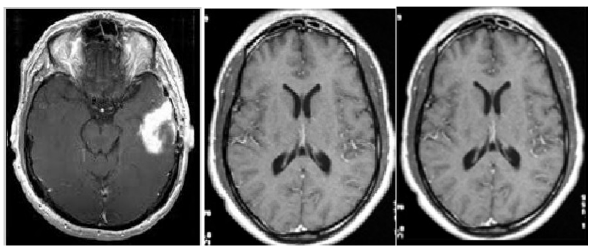
B. RMSE (Root Mean Square Error)

RMSE is used to compute the difference between the fused image and the source image. Smaller value of RMSE indicates better fusion performance. Here $'M'$ and $'N'$ represents the number of columns and rows respectively.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[R(i,j) - F(i,j)]^2}{M \times N}} \quad (6)$$

V. RESULTS

A. Image Registration Results



(a) (b) (c)

Fig. 3 (a) input MRI image 1, (b) input MRI image 2,(c)registered MRI image

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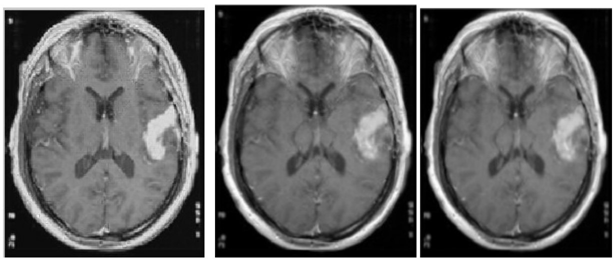
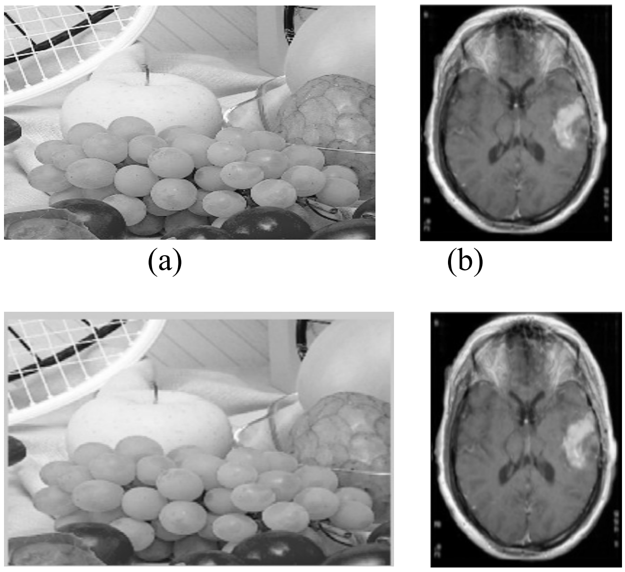
B. Image Fusion Results



(a) (b) (c)

Fig. 4 (a) Fused image-DWT method, (b) Fused image-Laplacian method, (c) Fused image-Combined method

C. Steganography Results



(a) (b)

(c) (d)

Fig. 5 (a) Cover image, (b) Message image, (c) Stego image,(d) Retrieved image

Table I. Quantitative analysis of different fusion methods

Fusion Rule	Metrics	
	PSNR(dB)	RMSE
DWT Method	17.23	34.87
Laplacian pyramid Method	17.30	34.59
Combined Method	17.71	33.18

VI. CONCLUSION

The two different brain images are fused using Laplacian pyramid based method and DWT based method. Results are combined using local structural similarity values as weights. The performance of the proposed scheme is evaluated using standard quality measures. It is observed that the fused image contains more useful information than the individual source images and individual fused image results. Fusion also reduces the storage spaces by enabling us to store a single informative image than multiple images. For the secure transmission of the fused image LSB insertion based steganography is also performed.

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