Study on Image Fusion Techniques Applicable to Medical Diagnosis

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Abstract—**In order to diagnose any disease accurately, medical practitioners require a complete set of data regarding anatomical and physiological information of the area of interest. Different medical imaging modalities are available, which gives either structural or functional information only. Image fusion is a suitable method to combine various multimodality medical images to form a single fused image with all relevant data. This paper gives a review and presents theoretical comparison on various image fusion techniques available for fusing the desirable multimodality medical images.**

Keywords— application, steps, pyramidal, transform, feature level, decision level.

I. Introduction

Image Fusion is a method that integrates the complementary details from multiple input images of the same scene into a single image, so that the resultant image will be more informative and complete than the input images. Two things to be noted during image fusion are: the fused image should preserve all relevant information from the input images and the fusion doesn't incorporate any unwanted information which will lead to wrong diagnosis. The input images can be multisensor, multimodal or multifocus [1].

Medical diagnosis relies on many image modalities, of which Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultra Sound (US), Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT) are common ones. Each modality is distinct from one another with its own features. CT scan image gives more information regarding dense structures like bones, but can't detect physiological changes, whereas MRI images are used to visualize normal or physiological soft tissues. Regarding the scanning procedures, CT scan requires the patient to be exposed to more radiations, whereas MRI scanning is time consuming and expensive. US is a useful modality with less cost and no radiation exposure but has the disadvantage of being completely dependent on operator skills [2]. PET gives better information regarding brain functionality [3]. It is practically impossible to capture all the details from one imaging modality for ensuring clinical accuracy. Therefore it is always a better choice to have a combined image incorporating the features of multiple modalities and making the diagnosis more reliable and accurate[4].

Multimodality image fusion is the process of registering and combining multiple images from single or multiple image modalities to improve image quality so that the fused image can be relied for diagnostic purpose. The additional information obtained from the fused images can be used for precise localization of abnormalities and helps in computer aided diagnosis. Thus in order to complement one modality feature with the other, one can use image fusion technique.

Areas of application of image fusion are [suggested as [5]:

- Medical domain: to obtain a high resolution image with as much as details as possible for diagnosis purpose.
- Automotive Industry: To enhance vision of road during rainy or foggy weather.
- Used for visual interpretation, digital classification, and remote sensing satellite and war field navigation.

A. *Methodoloy*

The block diagram shown in Fig. 1 explains the basic steps involved in implementing an image fusion technique. Steps Involved are:

a. Image Preprocessing:

- Image Registration: Identification, improvement and development of imaging modalities useful for medical image fusion. Various processes involved in image registration are: Applying a method to correct spatial misalignment between different image data sheets (transforming different sets of data into one co ordinate system) and applying a method to remove inter image noise, compensating missing features and outliers in the image.
- Image resizing
- Image enhancement: Contrast of input images are adjusted, so that images will have same range of values [6].

b. Applying the required image decomposition method for multiresolution analysis. For simple spatial fusion method this step can be avoided.

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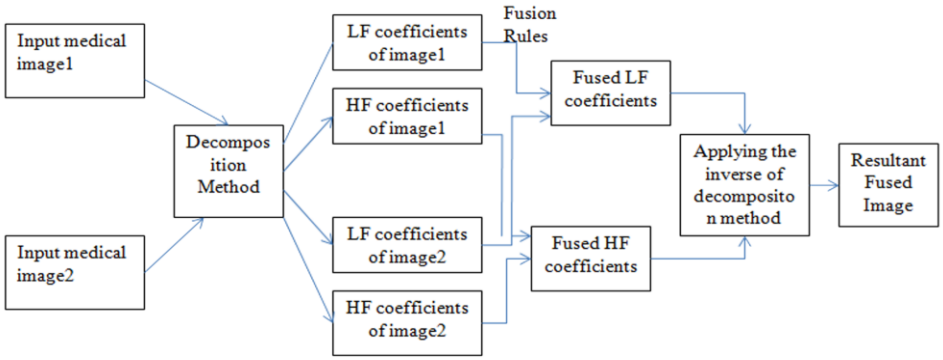

Fig.1 Image Fusion Technique

c. Development of different techniques for medical image fusion. Fusion of the features involve

identification and selection of features with a focus on relevance of features for a given clinical assessment purpose. For the two subband coefficients two separate fusion rules can be applied.

d. Do the inverse of the decomposition method on sub band coefficients to get the final fused image.

e. Do the performance analysis on the fused image using various quantitative metrics.

Inorder to compare the performance of various image fusion techniques some of the quantitative metrics available are:

- Peak signal to Noise Ratio (PSNR): It is the ratio of maximum possible power of signals to the power of corrupting noise the affects the fidelity of the image.
- Entropy: It is a measure of information quantity contained in an image.
- Mean square Error (MSE)
- Normalized cross correlation (NCC): NCC gives similarity index of the fused image with the registered input image [7].

B. Classification and Comparison

Image fusion techniques are mainly classified into three levels based on the parameter to be used for fusion: Pixel level, Feature level and Decision Level methods.

a. Pixel level method

It manipulates on direct image pixel level. It is again classified into

- Spatial domain method
- Transform domain method

Spatial domain method is the basic pixel level method ie, directly working on pixel value of the image. Since it is directly applied on source image the resultant image exhibits less Signal to Noise Ratio (SNR) and spatial distortion. Common methods coming under this category are: Simple maximum method, simple minimum method, simple average method, weighted average method, Independent and Principal Component Analysis (ICA & PCA), Intensity Hue Saturation (IHS) method [1].

Transform domain method, here image is first transformed into frequency domain and all fusion operations are performed on the frequency coefficients, and inverse transformation is done to get the resultant fused image. The resultant fused image contains energy compaction, all the details of source image and reduces spatial distortion. Based on the frequency domain transformation method, it is again classified into: pyramidal method and transform method [18].

- Pyramidal Method

Pyramidal methods are used for multiresolution analysis. An image pyramid contains all the information needed to reconstruct the original image. But it fails to introduce spatial orientation selectivity in the decomposition process and the fused image usually contains blocking effects [20]. The common pyramidal methods are: Guassian pyramid, Laplacian pyramid, contrast Pyramid, Filter Subtract Decimate Pyramid (FSD), morpholoical pyramid and gradient pyramid [8].

- Transform Method

Common transforms are based on wavelet decomposition and are: Discrete Wavelet Transform(DWT), Lifting Wavelet Transform(LWT), Redundant Discrete Wavelet Transform(RDWT), Contourlet Transform(CT), Dual Tree Complex Wavelet Transform(DT-CWT), Dual Tree Complex Contourlet Transform(DT-CCT), ridglet, curvelet, bandlet [7] and Non Subsampled Contourlet Transform(NSCT) [23]. Wavelet is an optimum decomposition tool for one dimensional (1D) signals, but not for multidimensional signals. It provides convenient data structures. Also wavelets

TABLE I. COMPARISONOFVARIOUS IMAGE ON TECHNIQUES

Sl No.	Image Fusion Technique	Category of Image Fusion	Advantages	Disadvantages
1.	Simple Max	Spatial Method	Simple method to implement image fusion	Reduces the contrast of source image and resulting in poor spatial quality
2.	Simple Min			
3.	Average Method			
4.	Weighted Average			
5.	PCA	Spatial Method	Simple method to implement and have high spatial quality.	The fused image shows spectral degradation
6.	IHS			
7.	Contrast Pyramid	Pyramidal Method	Suitable for multiresolution analysis	Will not retain sufficient information from its source image
8.	Morphological Pyramid			Creates false edges
9.	Ratio Pyramid			Provides false information which never existed in original image
10.	DWT	Transform Method	No blocking artifacts, better SNR, Optimum for 1D signals like scan line of an image.	Suffers from shift variance, Memory consuming, Poor real time operation, Higher computational complexity, Two dimensional(2D) DWT has limited ability to get directional information, Alaising and spatial distortions are prominent and hence fused image have blurring at contours.
11.	LWT	Transform Method	Makes calculations simpler and faster	Reduced directionality property, Shift variance property
13.	RDWT	Transform Method	Provides shift invariant property, Conserves important edge and spectral information with less spatial distortion.	Reduced directionality property
14.	CT	Transform Method	Improved directionality property (due to the presence of DFB) Computationally efficient, High degree of anisotropy, localization and multiscale [22]	Its basis images are not localized in frequency domain and less regularity in spatial domain [20]
15.	Curvelet	Transform Method	It preserves edge information [4]	
16.	DT-CWT	Transform Method	Provides approximate shift invariance	Has limited directional information
17.	DT-CCT	Transform Method	Retains shift invariance property, Improved directionality property by incorporating DFB	
18.	SF	Feature Level Fusion	Maintains spectral Integrity and enhances the spatial quality of image	
19.	Retina Based Fusion	Decision Level Fusion	Fused image preserves more spectral features with less spatial distortion	Computational complexity

decomposes images only in three directional high pass subbands ie, vertical, horizontal and diagonal or it can give only limited directional information [13]. To resolve these problems there exists so many variants of Wavelet Transform (WT).

b. Feature level method

It operates on features extracted from the input images. Feature based fusion techniques are relying on empirical or heuristic rules. Features involve edges, regions, shape, size, length or image segments and features with similar intensity. Among these Segment Fusion (SF) and Edge Fusion (EF) are taken into consider [19].

c. Decision level method

This method makes use of artificial intelligence to fuse the image. Eg: Morphological Methods, Knowledge based methods, Neural network based methods, Fuzzy logic based methods, biologically inspired fusion methods [1].

Many researchers have been done in the area of image fusion and some of the works are highlighted below. Table I. gives the advantages and disadvantages of some existing image fusion techniques.

F. Sadjadi [8] defined image fusion as the method of creation of a composite image, using different source images viewing the same scene. Hence the resultant image has more information content, which helps to detect and identify the targets even in the presence of adverse environmental conditions like dust, smoke or day and night. Various image fusion algorithms based on image pyramid, wavelet transform and biologically inspired fusion have been discussed. They have developed a toolbox named Image Fusion Evaluation Tool Box to measure the performance of image fusion algorithms.

H. Chen [9] proposed an image fusion algorithm where the images have been decomposed by multiresolution representation using wavelet. Thereafter the low frequency coefficients are fused by adaptive fusion weight value, determined by PCA and high frequency coefficients are fused by local wavelet energy maximum. Finally the fused image is obtained by inverse transforming and combining all wavelet coefficients.

L. Chiorean et al. [10] discussed about the various image registration and image fusion techniques. The image registration techniques have been mainly classified into three: Point based registration, Surface based registration and Volume based registration, based on the matching parameter. They had implemented and analyzed medical image fusion by DWT using Java Technology. The advantages of transform based method over simple methods are energy compaction, larger Signal to noise ratio (SNR) and reduced features. Among transforms, wavelet is chosen because it can be used for time frequency localization and can perform multi scale and multi resolution operations there by improving the spectral content of the resultant fused image. DWT has its disadvantage in which it is not shift invariant.

R. Singh et al. [11] proposed a fusion algorithm that combines the information from MRI images: T1 weighted,T2 weighted and proton density brain images, and tries to include the features of RDWT to incorporate the shift invariance property, mutual information based non linear registration and entropy information for image selection. It has been experimentally proved that the proposed algorithm conserves important edge and spectral information without much of spatial distortion.

M. Shahid et al. [12] discussed about image fusion on a different context ie, military application for providing better target detection and identification using a multisensory data fusion than a single wide band sensor. The fusion algorithm that have been used is DT- CWT based multiresolution. It is a form of DWT which generates complex coefficients using a dual tree of wavelet filters to obtain real and imaginary parts. DT-CWT has the advantage of shift invariance and directional selectivity over DWT. By applying DTCWT, image is subdivided into sub bands; Low Frequency (LF) is fused using basic fusion schemes whereas High Frequency (HF) band is fused by extracting edge information using customized masks. Various fusion rules for the selection and combination of sub band coefficients increases the quality of image fusion.

L. Yang et al. [13] elaborated on a new pixel level fusion algorithm for multimodality medical image based on CCT has developed. The Contourlet has the advantage of better directionality, better localization, anisotropy and multiscaling. Among the transform method DWT is the basic method and it is considered as the optimum tool for 1D signals and not good for high dimensional signals. 2D separable wavelets are good in isolating discontinuities at object edges, but cannot detect smoothness along the edges. Also wavelets decomposes images only in three directional high pass subbands, hence contains only limited directional information. To overcome these issues, Multiscale Geometric Analysis (MGA) tools have been used, of which important are: Ridgelet, Curvelet, Bandlet, Contourlet. Contourlet is a true 2D sparse representation of 2D signals like images. The fusion of LF and HF coefficients are based on local energy, weighted average and selection are combined with region concept for the selection of coefficients in the low pass and high pass subbands.

S. Rajkumar et al. [14] enumerated on different types of image fusion methods available in Fusion Tool of Matlab5.0. The majority of fusion techniques are based on WT. But DWT in medical image results in shift variant and additive noise in fused images. Image fusion using RDWT and CT along its comparison has been discussed. The image sets t have been chosen are CT and MRI-T2 FLAIR.

Y. Yanchun et al. [15] introduced an improved image fusion method based on LWT and Dual Channel Pulse Couple Neural Network (PCNN). It has been mentioned about the disadvantages of a conventional WT like memory consumption, poor real time and higher computational complexity. In order to overcome these difficulties Lifting WT have been chosen, which makes calculations simpler and faster. Dual Channel PCNN is a biologically inspired neural network, which has simpler network architecture with better adaptability, less time consuming and has less computational complexity, and is adopted as the fusion rule in HF subband coefficients. For LF subband coefficient the fusion rule used is based on region spatial frequency.

S. Daneshvar et al. [16] proposed a technique for the fusion of PET and T1 weighted MR images of the brain. After registration steps, the high frequency part of the MR is added to the PET image. The results have been showed that the merged images have improved quality when compared with Intensity Hue Saturation (IHS), DWT, wavelet atrous algorithm and wavelet based sharpening methods. The fusion algorithm is a multiresolution data fusion based on retinal

visual channels decomposition motivated by retina based image analysis. New application of the human vision system model in multispectral image fusion has been introduced. A computer retina model using difference of Gaussian operator has been implemented.

N. Al-Azzawi et al. [17] has been adopted the decomposition method as DT- CCT. The limitation of DT-CWT is lack of directionality, and has been rectified by including Directional Filter Banks (DFB) into the DT-CWT resulting in DT-CCT. DT-CCT retains the shift invariance property with improved contours and textures. To improve the fused image quality, the frequency components of DT-CCT coefficients are fused by: HF components uses PCA method and LF uses the salient features based on local energy. The wavelet transform used is bi orthogonal Daubechies and for DFB biorthogonal quincunx filetrs are designed.

K. Parmar et al. [18] has been implemented the image fusion technique using Fast Discrete Curvelet transform along with wrapper algorithm and compared with the conventional wavelet based fusion techniques. The input image sets selected are CT and MRI images. The curvelet transforms has got two versions, one is using unequally spaced Fast Fourier Transform(FFT) and the second one is based on wrapping of selected Fourier coefficients.

II.CONCLUSION

One of the main applications of image fusion technique is in medical domain, where computer aided diagnosis for the precise localization of abnormalities by integrating relevant information from various medical image modalities are helpful in disease cause and analysis. This helps the medical practitioners to have an efficient, fast and accurate clinical treatment. The paper reviews various image fusion techniques commonly used, with its advantages and disadvantages and opens avenues for research into optimizing the fusion method for getting the best resultant image which can lead to accurate medical diagnosis.

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