Various Techniques of Image Fusion

Ms. Dipixa H. Rana[1], Mr. Sheshang D. Degadwala[2]
[1]M.E Student, [2]Assistant Professor
[1,2]Computer Department
[1,2]Sigma Institute of Engineering, Vadodara

Abstract— 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. Medical Image fusion techniques can improve the quality of Image. Many techniques are available for image fusion. This paper presents review on some of image fusion methods based on both spatial and transform domains with their advantages and disadvantages. Here , also include various measurement like Peak Signal to Noise Ratio(PSNR), Entropy, Normalized Cross Correlation (NCC) which evaluated performance of the fused image.

Key words: Image Fusion, Discrete Wavelet Ttransform, Curvelet Transform, Contourlet Transform

I. INTRODUCTION

Image Fusion is the process of generating better quality image from two or more input images. The resultant image should retain all important features of all input images [2]. Image fusion technology can be applied to many areas dealing with images such as medical image analysis, remote sensing, military surveillance, etc [2]. As we know that medical imaging field demands more complementary information for disease diagnosis purpose. However, this is not possible using single modality medical images as X-ray computed tomography (CT) is suited only for recognizing bones structure, MRI giving clear information about the soft tissues and so on. In this regard, medical image fusion is the only emerging technique which has attracted researchers to assist the doctors in fusing images and retrieving relevant information from multiple modalities such as CT, MRI, FMRI, SPECT, PET [8].

Here, two input images from different image modalities are shown Fig 1 and Fig 2 . First image is a Computed Tomography (CT) image and the second image is a Magnetic Resonance Imaging (MRI). Each image has its own limitation, which can be solved by creating the fused image from two different image modalities as shown Fig 3. This would lead to improved diagnosis, better surgical planning, more accurate radiation therapy and countless other medical benefits [2].

Each image has its own limitation, which can be solved by creating the fused image from two different image modalities as shown Fig 3. This would lead to improved diagnosis, better surgical planning, more accurate radiation therapy and countless other medical benefits [2]. The main advantage of Image fusion (IF) is integrating complementary, as well as redundant information from multiple images to create a fused image for providing more complete and accurate information. Another advantage of image fusion is that it reduces the storage cost by storing only the single fused image, instead of the multisource images. Image fusion takes place at three different levels i.e. pixel, feature and decision [9]. Pixel level is a low level of fusion which is used to analyze and combine data from different sources before original information is estimated and recognized [9]. Feature level is a middle level of fusion which extract important features from an image like shape, length, edges, segments and direction [9]. Decision level is a high level of fusion which points to actual target [9].

This paper is structured in the following way: Section 1 gives introduction to image fusion. Section 2 provides details on several image fusion methods. Section 3 defines a set of image fusion measurement. Section 4 provides conclusions.

II. IMAGE FUSION TECHNIQUES

Image Fusion methods can be broadly classified into two that is spatial domain fusion and transform domain fusion [9].

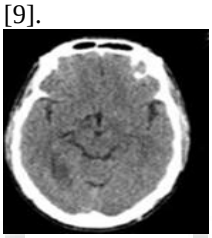
Fig. 1: CT Image

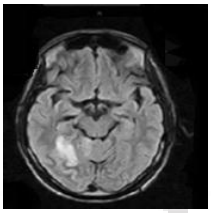
Fig. 2: MRI Image

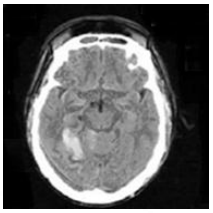
Fig. 3: Fused Image

A. Spatial Domain Image Fusion Methods

Spatial image fusion methods work by combining the pixel values of the two or more images to be fused in a linear or non- linear way [6]. This simplistic approach oft-en has serious side effects. Pixel level image fusion methods are affected by blurring effect which directly affect on the contrast of the image [6]. The limitations of Spatial Domain are resolved by Transform Domain. Some well-known Spatial Domain Image Fusion methods are listed below :

- Averaging
- Brovey Method
- Principal Component Analysis (PCA)
- IV . Intensity-Hue-Saturation (IHS)
- V . Select Maximum Method
- VI . Select Minimum Method

1) Averaging

Average Method working as averaging every corresponding pixel of input images to obtain final fused image [8]. It is define as:

$$\boldsymbol{F(x,y)} = \frac{\boldsymbol{A(x,y)+B(x,y)}}{\mathbf{2}} \qquad (\mathbf{1})$$

Where, F(x, y) is the final fused image, A(x, y) and B(x, y) are two input images.

2) Brovey Method

This method is developed and supported by an American scientist. Brovey method is also known as color normalization transform because it contains a red-green-blue (RGB) color transform method. The Brovey transformation was developed to avoid the drawbacks of the multiplicative method. It is a simple method for combining data from different sensors. In this method combination of arithmetic

operation are used and spectral bands are normalized before they are multiplied with the panchromatic image. It also retains the corresponding spectral feature of each pixel and transforms all the luminance information into a panchromatic image of high resolution [8]. The limitation of Brovey image fusion method is that produce spatial distortion in fused image. This problem can be solved by transform domain fusion.

3) Principal Component Analysis (PCA)

PCA is a mathematical tool which transforms a number of correlated variables into a number of uncorrelated variables. The PCA is used extensively in image compression and image classification. The PCA involves a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. It computes a compact and optimal description of the data set. The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible. First principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first. Within this Subspace, this component points the direction of maximum variance. The third principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on. The PCA is also called as Karhunen-Loève transform or the Hotelling transform. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. and its basis vectors depend on the data set [10].

4) Intensity-Hue-Saturation (IHS)

The IHS fusion [3] converts a color image from the RGB (Red, Green, Blue)space into the IHS color space. Because the intensity (I) band resembles a Pan image, it is replaced by a high-resolution Pan image in the fusion. A reverse IHS transform is then performed on the Pan together with the hue (H) and saturation (S) bands, resulting in an IHS fused image. It is simple method to merge the images attributes and provide a better visual effect but produces a significant color distortion with respect to the original image. The disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image. Spectral distortion becomes a negative factor while we go for further processing, such as classification problem. Spatial distortion can be very well handled by frequency domain approaches on image fusion.

5) Select Maximum Method

The greater the pixel values the more in focus the image. Thus this algorithm chooses the in focus regions from each input image by choosing the greatest value for each pixel, resulting in highly focused output. The value of the pixel P (i, j) of each image is taken and compared to each other. The greatest pixel value is assigned to the corresponding pixel [10].

6) Select Minimum Method

This is similar to the select maximum method but with the difference, it considers only the pixel with lowest intensity value and ignores all other values. This method also has the disadvantage of either completely considering information or discarding it fully [8].

B. Transform Domain Image Fusion Methods

In Transform Domain, Image is first transferred into frequency domain. All the Fusion operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image [3]. Wavelet Trans-form is faster developed multi-resolution analysis image fusion method.

The problem with Wavelet Transform (WT) is that, it can preserve spectral information efficiently but cannot express spatial characteristics well [7]. So, Recently, a theory called Multi-scale Geometric Analysis has been developed. Many MGA tools were proposed, such as Curvelet, Contourlet, Ripplet etc. Which have higher directional sensitivity [1].Some well-known Transform Domain Image Fusion methods are listed below :

- Discrete Wavelet Transform
- Curvelet Transform
- Contourlet Transform
- Discrete Ripplet Transform

1) Discrete Wavelet Transform

Discrete Wavelet Transform provide directional information in decomposition levels and contain unique information at different resolutions [1].

The fusion procedure based on wavelet transform can be described as follows.

1. The images to be fused must be registered to assure the corresponding pixels are aligned [3].
2. These images are decomposed into wavelet transformed images respectively, based on wavelet transformation. The transformed images include one low frequency portion (low-low band) and three high frequency portions (low-high bands, high-low bands, and high-high bands) [3].
3. The transform coefficients of different portions or bands are performed with some fusion rules [3].
4. The fused image is constructed by performing an inverse wavelet transform based on the combined transform coefficients from step 3 [3].

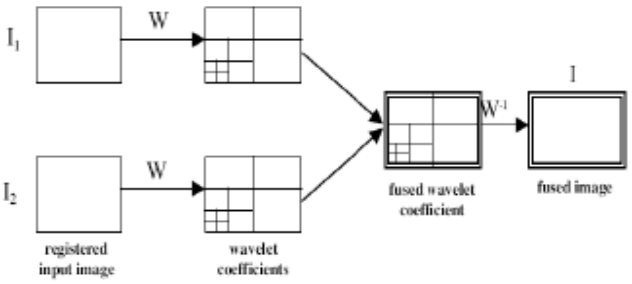

Fig. 4: Block Diagram Of DWT based Image Fusion[3]

2) Curvelet Transform

The curvelet transform is a very young signal analyzing method with good potential. It is recognized as a milestone on image processing and other applications. Curvelet transform is more accurate to deal with the curve than wavelet transform the below Fig. 5 shows this [11].

Wavelet approach Many wavelet coefficients are needed to account edges. i.e. singularities along lines or curves needed to account edges [11]. Curvelet approach Less coefficients are needed to account edges [11].

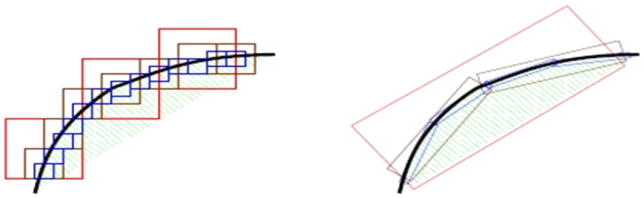

Fig. 5: Difference between Curvelet and Wavelet Transform

3) Contourlet Transform

Contourlet Transform is a "real" two dimen -sional image representation proposed by Minh N.Do and Martin Vetterli [5] in 2002. Contourlet Transform is achieved by two steps: Laplace pyramid decomposition (LP) and directional filter banks (DFB) filtering. Firstly, decompose the original image into one low-pass sub-image and one band-pass sub-image by LP decomposition. The band-pass sub-image is the difference image between the original image and the low-pass prediction image. Then decompose the band-pass sub-image into several direction sub-bands through the directional filter banks. Repeat above process to the low-pass sub-band will achieve multi-resolution and multi-directional decomposition of the image. Contourlet transform not only has multi-scale and time frequency local characteristics, but has directional characteristic that can accurately capture the image edges into different scales and different frequency sub-bands [5].

4) Discrete Ripplet Transform (DRT)

The Conventional transforms like Fourier Transform and Wave Transform suffer from discontinuities such as edges and contours in images. To address this problem, Jun Xu etal. proposed a new MGA-tool called RT. The RT is a higher dimensional generali-zation of the Curvelet Transform (CVT), capable of representing images or 2D signals at different scales and different directions [4]. Visual and quantitative analysis shows, that the Ripplet Transform technique performs better compared to fusion scheme based on Contourlet Transform (CNT) [4]. RT generalizes CVT by adding two parameters, i.e., support c and degree d. CVT is just a special case of RT with c = 1 and d = 2 [4].

Comparative study of various Spatial Domain Fusion Methods and Transform Domain Fusion Methods are shown in Table 1.

Image Fusion Method	**Advantage**	**Disadvantage**
Averaging Method	This is simplest method of image fusion	This method is affected by blurring effect which directly affect on the contrast of the image.
Brovey Method	This is simplest and fast method	This method produce spectral degradation
IHS Method	It is a simple method to merge the images attributes and provides high spatial quality	It suffers from artifacts and noise which tends to higher contrast. It causes color distortion. The major limitation that only three bands are involved
PCA Method	This method Provide higher spatial quality	This method produce spectral degradation
Select Maximum	highly focused image output obtained from the input image as compared to average method.	This method is affected by blurring effect which directly affect on the contrast of the image.
Select Minimum	This is simplest method	This method also has the disadvantage of either completely considering information or discar-ding it fully
Discrete Wavelet Transform	The DWT fusion method has least spec-tral distortion. It also provides better PSNR than pixel based approach. Multiresolutoin, localization and critical sampling is provided by wavelet.	In this method final fused image have a less spatial resolution. It does not provide directionality.
Curvelet Transform	Curvelet approach Less coefficients are needed to account edges. Multi-Scaling is provided by Curvelet.	CVT is just a special case of RT with c = 1 and d = 2[4]
Contourlet Transform	Multi-scaling,directionality,Multi-resolution, localization are provided by Contourlet.	Visual and quanti-tative analysis shows, that the Ripplet Transform technique performs better compared to fusion scheme based on Contourlet Transform (CNT) [4].
Discrete Ripplet Transform	Multi-scaling,directio-nality, localization are provided by Ripplet.	It does not provide Multi-Resolution.

Table 9: Comparison table

III. PERFORMANCE MEASURES PARAMETER OF FUSION TECHNIQUES

A. Entropy

Entropy is one of the most important quantitative measures in image fusion. A digital image consists of pixels arranged in rows and columns. Each pixel in Image is defined by its position and gray scale level. For an image consists of L gray levels, the entropy is defined as [8]:

$$E = -\sum_{i=0}^{L-1} p_i \log_2 p_i \quad (2)$$

Where, P(i) is probability of each grey scale level.

B. Peak Signal To Noise Ratio(PSNR)

Peak Signal To Noise Ratio [2] can be given as follow:

$$PSNR = 10 \times \log_{10}\left(\frac{{f_{max}}^2}{MSE}\right) \quad (3)$$

Where, $f_{max}$is maximum gray scale value of the pixels in fused image, the higher the value of the PSNR, the better the fusion result.

C. Normalized Cross Correlation(NCC)

It used to find out similarities between fused image and registered image is given by the following equation [2]:

$$NCC = \sum_{i=1}^{m}\sum_{j=1}^{n}\left(F_{ij} \times R_{ij}\right) \Big/ \sum_{i=1}^{m}\sum_{j=1}^{n} {F_{ij}}^2 \quad (4)$$

Where, R is original image (or one of the source images) and F is the fused image. m and n are the dimensions of the images.

IV. CONCLUSION

This review results that spatial domain provide high spatial resolution. But spatial domain have image blurring problem. But these are much useful and simpler in case of high contrast and bright images. The limitation of Spatial Domain is overcome by Transform Domain. Finally this review concludes that a image fusion algorithm based on combination of DWT and DRT will improve the image fusion quality.

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