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Image Fusion: Different Methods and Performance Evaluation Metrics

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***Abstract*- Medical image fusion is the process of registering and combining multiple images from single or multiple imaging modalities to improve the imaging quality and reduce randomness and redundancy in order to increase the clinical applicability of medical images for diagnosis and assessment of medical problems. Multi-modal medical image fusion algorithms and devices have shown notable achievements in improving clinical accuracy of decisions based on medical images. This paper explains the concept of image fusion. It explains how image fusion is advantageous. In this paper different techniques have been reviewed for combining multispectral images available. It includes IHS transform, High Pass filtering, PCA analysis, Wavelet transform and DCT, Graph Cut method.**

***Keywords*— Image fusion techniques, Wavelet method, Graph cut method**

I. INTRODUCTION

Image Fusion is one of the major research fields in image processing. Image Fusion is a process of combining the relevant information from a set of images, into a single image, wherein the resultant fused image will be more informative and complete than any of the input images. Image fusion process can be defined as the integration of information from a number of registered images without the introduction of distortion. It is often not possible to get an image that contains all relevant objects in focus. One way to overcome this problem is image fusion, in which one can acquire a series of pictures with different focus settings and fuse them to produce an image with extended depth of field. Image fusion techniques can improve the quality and increase the application of these data. One of the important pre-processing steps for the fusion process is image registration, i.e., the coordinate transformation of one image with respect to other. Fusion algorithms are input dependent .Image fusion find application in the area of navigation guidance, object detection and recognition, medical diagnosis, satellite imaging for remote sensing, rob vision, military and civilian surveillance, etc.

Image fusion systems are widely used in surveillance and navigation applications, for both military and domestic purposes. This is achieved by the use of multiple sensors to obtain the visual information and by utilizing the synergism of different imaging sensors for better situation assessment Image fusion means combining the two images into a single image that has maximum information content without producing details that are non-existent in the given images.

A fusion process is a combination of salient information in order to synthesize an image with more information than individual image and synthesized image is more suitable for visual perception. These images may be obtained from different types of sensors. In other words, image fusion is a process of combining multiple input images into a single fused image which preserves full content information and also retaining the important features from each of the original image.

The main purpose of medical image fusion is to obtain a high resolution image with as much details as possible for diagnosis of disease and better medical treatment. For medical diagnosis, MR and CT images are of main concern, both images give special sophisticated characteristics of the organ to be imaged. MR image provides better information about soft tissue and CT image provides detail information about dense structure such as bones. These two images provide complementary information. So it is expected that, fusion of these two images of the same organ would results into an integrated image which contains as much information as possible for diagnosis of that organ [2].

The fusion of multiple measurements can reduce noise and therefore eliminates their individual limitations. The fused image should preserve as closely as possible all relevant information obtained in the input images and fusion process should not introduce any inconsistencies which can mislead or distract the medical professional, thereby guiding them for wrong diagnosis.

Sharmila et al. (2013) [4] has shown that multimodality medical image fusion using discrete wavelet transform and entropy concepts provides better quality of

information and less noise in the fused image formed. Medical image fusion is the s the technique of deriving very important data simply by incorporating multimodality medical images like computed tomography (CT), Magnetic resonance imaging (MRI), Positron emission tomography (PET) and single photon emission computed tomography (SPECT) into single image . The information thus derived can be used for various purposes such as for diagnosing diseases, detecting tumour, surgery treatment etc. Single modality image cannot provide this useful information.

II. IMAGE FUSION TECHNIQUES:

Image fusion techniques can enhance a digital image without spoiling it. The enhancement methods are of two types namely Spatial domain methods and frequency domain methods. In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement.

The fusion methods, such as averaging, the Brovey method, principle component analysis (PCA), and IHS based methods fall under the spatial domain approaches. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values.

The flow chart of the image fusion process is as follows:

The MR is registered to the CT image. The CT is thresholded and its histogram is adjusted to match the MR image and finally the images are fused.

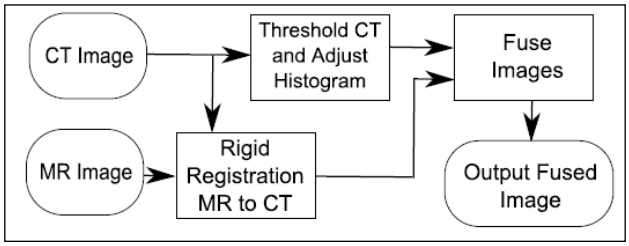

Figure 1: Flow chart of fusion process

The different types of image fusion techniques are as follows:

Principal Component Analysis (PCA)

1. The input image is transformed into number of principal components.
2. Each principal component has unique details of the image.
3. The mean and variance of the PCAs are calculated and the PCAs are replaced by the images which are stretched to have the same mean and variance.
4. This is continued for all the PCAs.
5. The inverse transform is calculated and the final new fused image is obtained.

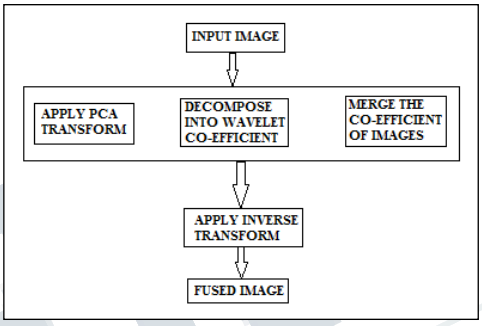

Figure 2

2. IHS (Intensity-hue-saturation):

IHS transform method is the oldest method of image fusion Hue (H) refers to the average wavelength of the light contributing to the color, Intensity (I) the total brightness of the color, saturation(S) is the purity of the color. In the HIS space, hue and saturation need to be carefully controlled because it contains most of the spectral information.

Steps to perform image fusion are as follows: the registration between high resolution image and multispectral image, division of multispectral into I,H,S, replacement of I using high space resolution panchromatic image to get another element I', then inverse HIS transform using I',H,S to get fused image.

3. Curvelet Transform

Curvelet transform is a multiscale directional transform useful for analysis of image edges having curve shape objects. It was proposed by E.J Candes and D.L.Donoho in 2000 which uses ridgelet analysis applied on the radon transform. However, Ridgelet based curvelet transform is not efficient as it uses complex series of ridgelet transform. In 2005, Candes et al. proposed a newly constructed curvelet transform known as fast discrete curvelet transform which is faster, simpler and less redundant than ridgelet transform. Two fast discrete curvelet transform were proposed-1. Based on unequally spaced FFT 2. Based on wrapping of specially selected Fourier samples

4. Pyramid Decomposition based fusion

Pyramid Fusion Algorithm is a fusion method in the transform domain. Various Pyramid based fusion techniques are FSD Pyramid, Laplacian Pyramid, Ratio-of-low-pass Pyramid, Gradient Pyramid, Morphological Pyramid contrast can be used for the image fusion using different fusion rules. In pyramid approach, pyramid levels obtained from the down sampling of source images are fused at pixel level depending on fusion rules. The fused image is obtained by reconstructing the fused image pyramid.

5. Wavelet based Fusion Method

Wavelet analysis was firstly invented in 1980, and since then many researches of both theoretical and application aspects of wavelet transform have been carried out[12].

Discrete wavelet transforms based image fusion is the simplest kind of image fusion. In this the source images are divided into lower and higher sub bands. The pixel having largest wavelet coefficients are selected for operation.

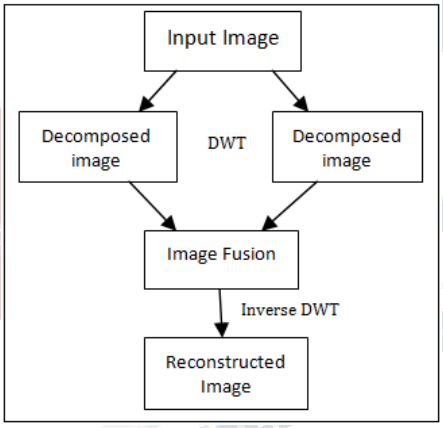

Figure 3

Dwt performs a transformation of image in spatial domain to image in frequency domain. Two dimensional subband coding algorithm for DWT is as follows: The source image is decomposed into rows and columns by low pass(L) and high pass (H) filtering and subsequent downsampling at each level to get approximation(LL) and detail (LH, HL,HH) coefficients. The final step in DWT technique is the application of inverse discrete wavelet transform to the processed image. The major advantage by using DWT is that it preserves coefficient information since it uses different fusion rules so it provides better SNR.

6. Discrete Cosine Transform (DCT)

DCT based fusion methods need less energy as compare to the DWT techniques thus it is appropriate to use DCT fusion methods for resource constrained devices. As computational energy required is less than the transmission energy, data is compressed and fused before transmission in automated battlefields where the robots collect image data from sensor network. In this technique input images and fused images both are coded in JPEG (Joint Photographic Experts Group) format. Contrast sensitivity method is used to form the fused image. The contrasts of the consequent AC (Alternating current) coefficients of different blurred images are compared and the AC coefficient having the largest value is particularly chosen as the AC coefficient for the image formed after fusion. DCT representation of the fused image is found by calculating the average of all the DCT representations of all the input images but it has unwanted blurring effects which decreases the quality of the fused image.

7. HIGH PASS FILTERING (HPF)

The high resolution multispectral images are obtained from high pass filtering. The high frequency information from the high resolution panchromatic image is added to the low resolution multispectral image to obtain the resultant image. It is performed either by filtering the High Resolution Panchromatic Image with a high pass filter or by taking the original HRPI and subtracting LRPI from it. The spectral information contained in the low frequency information of the HRMI is preserved by this method.

8. Graph Cut

First of all, we introduce the basic terminology. Let G = (V, E) be a graph which consists of a set of nodes V and a set of directed edges E that connect them. The nodes set V = {s, t} ∪ P contains two special terminal nodes, which are called the source, s, and the sink, t, and a set of non-terminal nodes P. In Figure 1(a) we show a simple example of a graph with the terminals s and t. Such N-D grids are typical for applications in vision and graphics. Each graph edge is assigned some nonnegative weight or cost w(p, q). A cost of a directed edge (p, q) may differ from the cost of the reverse edge (q, p). An edge is called a t-link if it connects a non-terminal node in P with a terminal. An edge is called a n-link if it connects two non-terminal nodes. A set of all (directed) n-links will be denoted by N. The set of all graph edges E consists of n-links in N and t-links {(s, p), (p, t)} for non-terminal nodes p € P.

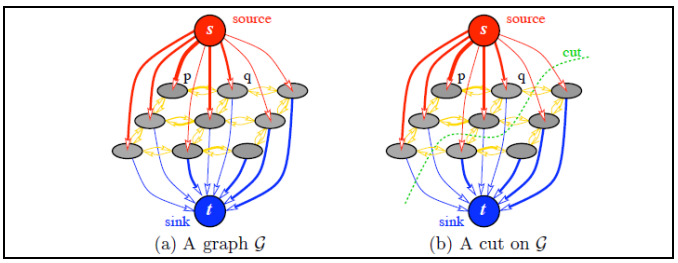

Figure 4 (a) Graph Construction (b) Graph Cut

III. PERFORMANCE EVALUATION METRICS:

1. Mutual Information measures the amount of information or detail that is common in both the input image and the resultant image.

2. Peak Signal-to-Noise Ratio is the ratio between the reference signal and the distortion signal in an image

3. Entropy is the measure which describes the business of an image, i.e. the information that is coded by a compression algorithm

4. SSIM(Structural similarity metric) is a full reference quality measure that measures the similarity between images. It is the efficient metric and is the improved one than PSNR and MSE. SSIM index is having values between 0 and 1 where 1 denotes the exact same image.

5. Standard deviation is the square root of variance, reflects the spread in the data. It represents the deviation of pixel values from mean. So, the value of Standard deviation should be high for better contrast of an image.

IV. CONCLUSION

This paper performs the Comparative study of Image fusion techniques and the related work. Here, various techniques of Image Fusion that are useful in image fusion is to fuse the medical based images have been discussed. On the basis of the study we have find out various issues in different techniques and to remove them various techniques are proposed for fusion of different images. The performance evaluation metrics can be used to compare different methods. The combination of different available methods can be used to achieve better outputs.

V. ACKNOWLEDGMENT

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