IMAGE FUSION TECHNIQUES AND PERFORMANCE EVALUATION FOR CLINICAL APPLICATIONS: A REVIEW

Sinija.T.S

MTECH, Department of computer science

Mohandas College of Engineering

Sinija33@gmail.com

Karthik.M

Assistant professor in CSE

Mohandas College of Engineering

karthikcpta@gmail.com

Abstract---

Image fusion process can be defined as the integration of information from a multiple 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. The importance of information offered by the medical images for diagnosis support can be increased by combining images from different compactable medical devices. Medical image fusion has been used to derive useful information from multimodality medical image data Fused image will be represented in format capable for computer processing. Image fusion can be performed by means of wavelet transform, complex wavelet transform, non sub sampled contourlet transform, etc. The resulting image contains more information compared to individual images. This paper describes different techniques and aspects of image fusion for multimodal medical imaging.

Keywords---**Multimodal medical imaging, image fusion, Wavelet transform Contourlet transform.**

1. INTRODUCTION

Processing the image and gathering the hidden information from a noised or blurred image can be carried out by various methods. Various techniques such as image fusion and super resolution enhances the image quality to show hidden information in processing the image. Image fusion is the process of combining relevant information from two or more images into a single image. Then the resultant image has more information than input images. Image fusion has become a topic of great interest to the engineers working in different fields. It's being used for medical applications, so as to get a better image.

It's also being used in automotive industries to enhance the vision of road, to observe a better image during a rainy weather.

Image fusion aims at synthesizing information from multiple source images to obtain a more accurate, complete and reliable fusion image for the same scenes or targets. Compared with original inputs, the fused image is more suitable for observation, analysis, understanding and recognition.

Structural images like Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Ultrasonography (USG), Magnetic Resonance Angiography (MRA), etc provide high resolution images with anatomical information. On other hand Functional images such as Position Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), Functional MRI (fMRI), etc, provide low resolution images with functional information. A single modality of medical image cannot provide comprehensive and accurate information. Combining anatomical and functional medical images provide more useful information through image fusion.

The new fused image generated contains more accurate description of the scene then any of the individual source image and is more suitable for human visual and machine perception or further image processing and analysis tasks. Several fusion algorithms starting from simple pixel based to sophisticated wavelets and PCA based are available. Image fusion system has several advantages over single image source and resultant fused image should have higher signal to noise ratio, increased robustness and reliability in the event of sensor failure, extended parameter coverage and rendering a more complete picture of the system.

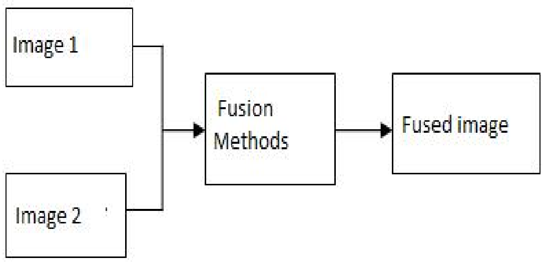

Figure 1.Image Fusion

Two images image 1 and image 2 of same or different modalities are taken and by applying the various fusion methods final fused image is obtained which is more informative than single image.

Multimodal medical image fusion not only helps in diagnosing diseases, but it also used to reduces the storage cost by reducing storage to a single fused image instead of multiple source images.

There are some important requirements for the image fusion process [1].

- The fused image should preserve all relevant information from the input images.
- The image fusion should not introduce artifacts which can lead to a wrong diagnosis.

The image fusion technique has been categorized into three categories. These include pixel level, feature level and decision level fusion where multimodal medical image fusion usually employs the pixel level fusion due to the advantage of containing the original measured quantities.

2. IMAGE REGISTRATION

One important step before fusion process is image registration. Multimodality registration means the matching of same scene acquired from different sensors. According to the matching features, the medical image registration process can be divided into three categories.

2.1. *Point Based Registration*

The method involves the determination of the coordinates of corresponding points in different images and the estimation of geometrical transform using corresponding points.

2.2. *Surface based registration*

Surface based registration involves the determination of the surfaces of the images to be matched and the minimization of a distance measure between these corresponding surfaces.

2.3. *Volume based registration*

Volume based registration involves the optimization of a data quantity measuring the similarity of all geometrically corresponding voxel pairs , considering some predefined features.

3. IMAGE FUSION TECHNIQUES

3.1 *Basic Levels of Image Fusion*

Image fusion can be divided into three levels:

- Pixel-level fusion
- Feature-level fusion
- Decision-level fusion.

Pixel Level Fusion:

Pixel level fusion generates a fused image in which information content associated with each pixel is determined from a set of pixels in source images. Fusion at this level can be performed either in spatial or in frequency domain. However, pixel level fusion may conduct to contrast reduction.

Feature Level Fusion

Feature level fusion requires the extraction of salient features which are depending on their environment such as pixel intensities, edges or textures. These similar features from the input images are fused. This fusion level can be used as a means of creating additional composite features. The fused image can also be used for classification or detection.

Decision Level Fusion

Decision level is a higher level of fusion. Input images are processed individually for information extraction. The obtained information is then combined applying decision rules to reinforce common interpretation.

3.1. *Fusion Using Logical Operators*

This technique uses logical operators. One image is the reference image and it is not processed. From the second image is established a region of interest and the information from these images are then combined. The simplest way to combine information from the two images is by using a logical operator, such as the XOR operator.

3.2. *Fusion Using a Pseudo-color Map*

In this fusion technique, the registered image is rendered using a pseudo-color scale and is transparently overlaid on the reference image. A pseudo-color map is defined as a correspondence of an (R, G, B) triplet to each distinct pixel value.

3.3. *Clustering Algorithms for Unsupervised Fusion of Registered Images.*

In this technique the fusion is realized by processing both registered images in order to produce a fused image with an appropriate pixel classification. The method uses the double histogram P(x,y) of the two registered images.

3.4. *The K-Means Algorithm*

K-Means Algorithm is a partitioned clustering algorithm, which is used to distribute points in the feature space among a predefined number of classes. This algorithm is applied to the n-dimensional histogram of the images to be fused.

3.5. *The Fuzzy K-Means Algorithm*

This technique is a variation of K-Means algorithm, with the introduction of fuzziness in the form of a membership function. The membership function defines the probability with each image pixel belongs to a specific class.

3.6. *Fusi on to Create Parametric Images*

This method is useful for fusion of information from a series of images of a dynamic study to classify tissues according to a specific parameter. The use of this technique leads to a parametric image which visualizes pixel by pixel the value of the parameter useful for the diagnosis.

3.7. *Fusion at the object level.*

Fusion at object level involves the generation of either a spatio-temporal model or a 3-D textured object of the required object. Segmentation and triangulation algorithms must be performed prior to the fusion process.

4. IMAGE FUSION ALGORITHMS

There are various image fusion techniques

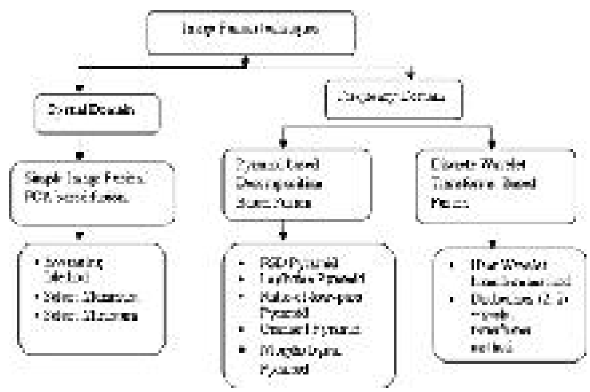

Figure 2. Image Fusion Techniques

4.1. Spatial Domain Fusion

Average Method

This method takes the average of two images pixel by pixel. This types work well when the image which are to be fused are from the same type of sensor and contains the additive noise. One limitation is some noise may introduce into fused image which reduce final image quantity [2].

Brovery Transform

This method preserves the relative spectral contribution of each pixel but replaces the overall brightness with high resolution panchromatic images. This is fast and simple method. One disadvantage is it produces spectral distortion [3].

Intensity Hue Saturation

This method uses three low resolution multispectral images in different bands and transforms them into IHS space is replaced by the high resolution panchromatic image and transformed back into original RGB space with previous H as well as S components. This method gives good visual effect but produces color distortion [4].

4.2. Transform Domain fusion

Pyramid Method

Image pyramid be described as the collection of low or band pass copies of original image in which both the limit as well as sample density are reduced in regular steps. The main strategy of image fusion based on pyramid method is the use of feature selection rule for constructing the fused pyramid representation from the pyramid representation of the original images. By taking inverse pyramid transform the composite image is obtained [5].

Wavelet based method

The most common form of image fusion is wavelet transform fusion. The transformed images are combined in the transform domain using a defined fusion rule then transformed images are combined in the transform domain using a defined fusion rule then transformed back to the spatial domain to give the resulting fused image.

Later improvements have been obtained in image fusion process with introduction of multi resolution analysis (MRA), by employing several decomposition schemes, specially based on discrete wavelet transform, uniform rational banks, and Laplacian pyramids.

5. REVIEWS OF MEDICAL IMAGE FUSION

4.1. *Medical image fusion by wavelet transforms modulus maxima.*

Guihong Qu, Dali Zhang proposed this paper. Using wavelet transform, they achieved a fusion scheme. A fusion rule is proposed and used for calculating the wavelet transform modulus maxima of input images at different bandwidths and levels. To evaluate the fusion result, a metric based on mutual information (MT) is presented for measuring fusion effect. This evaluates the statistical dependence between the fused and original image [6].

4.1.1. Advantages

- A better preservation of component information
- Fusion can be performed at different levels and bandwidths.

4.1.2. Disadvantages

- Not good at edge features.
- Limitations in the fusion of curved shapes.

4.2. *Medical image fusion based on discrete wavelet transforms.*

Ligia Chiorean, Mircea_Florin Vaida proposed this paper. This paper based on Discrete Wavelet transform.DWT transforms a discrete time signal to a discrete wavelet representation. It converts an input series X0, X1,..… Xm into one high pass wavelet coefficient series and on low pass wavelet coefficient series. The DWT has been extensively employed for remote sensing data fusion [7].

4.2.1. Advantage

- Simple and easy to understand and implement.

4.2.2. Disadvantages

- Some noise may introduce in fused image.
- Low accuracy for curved edges.

4.3. Curvelet *Fusion of MR and CT images.*

F.E Ali, L.M.El_Dokany, A.A.Saad proposed this paper. Curvelet Transform is based on the segmentation of whole image into small overlapping tiles and then the ridgelet transform is applied to each tile. The segmentation process is to approximate curved lines by small straight lines. The overlapping of tiles aims at avoiding edge effects. The curvelet transform was proposed for image de-noising [8].

4.3.1. Advantages

- Deal with images having curved shapes.
- Curved visual details are better.
- Image denoising.

4.3.2. Disadvantages

- Limited directional information along vertical, horizontal and diagonal directions.

4.4. *Redundancy Discrete wavelet Transform and Contourlet Transform for multimodality medical image fusion with quantitative Analysis*

S.Rajkumar, S.Savitha proposed this paper. Redundant discrete wavelet transform a variant of wavelet transform, is used to overcome the shift variance problem of DWT. Contourlet offers a highly efficient image representation on fused image. The methods used are Laplacian pyramid to avoid leaking of low frequency component into several directional components and Directional filter bank to capture high frequency components representing directionality [9].

4.4.1. Advantages

- Multi-resolution
- Localization
- Directionality

4.4.2. Disadvantages

- Computational Complexity
- High memory Consumption

4.5. *Medical Image Fusion based on Ripplet Transform Type-1.*

M.Chowdhury and M.K.Kundu proposed this paper. Medical image fusion method, based on Ripplet Transform for specially registered, multi-sensor, multi-resolution tool, capable of resolving two dimensional singularities and representing image edges more efficiently. The source medical images are first transformed by Discrete RT. Different fusion rules are applied to the different sub-bands of the transformed images. Then inverse DRT is applied to fuse Coefficients to get the fused image. The performance of the proposed scheme is evaluated by various quantitative measures like mutual information, spatial frequency and Entropy etc. Visual and quantitative analysis shows that this technique performs better compared on Contourlet Transform [10].

4.5.1. Advantage

- Capable of resolving 2D singularities.
- Representing image edges more efficiently.

4.5.2. Disadvantage

- Computational Complexity

4.6. *Biological Image Fusion using a NSCT based variable-weight method.*

T. Li, Y. Wang proposed this paper. Intensity Hue-saturation method derives the gray image for the intensity component of the color image and thus handles the fusion of gray level and color image. The implementation of the GIHS method from the traditional IHS method gives the specific location. By allocating redundancy and the invariance leads to less sensitivity to the image shift can be targeted in the NSCT. Compared to contourlet Transform, the Gibbs Phenomenon suppresses the coefficient modification to a great extent, since the interpolation of many filter techniques replaces the image decimation [11].

4.6.1. Advantages

- Gives exact estimation
- Robust in Nature

4.6.2. Disadvantage

- Obtaining better results with MRI and PET images is difficult.

4.7. *Directive Contrast Based Multimodal Medical Image Fusion in NSCT Domain*

Gaurav Bhatnagar, Member, IEEE, Q.M. JonathanWu, Senior Member, IEEE, and Zheng Liu, Senior Member, IEEE. In this paper, a novel fusion framework is proposed for multimodal medical images based on non-subsampled contourlet transform (NSCT). The source medical images are first transformed by NSCT followed by combining low- and high-frequency components. Two different fusion rules based on phase congruency and directive contrast are proposed and used to fuse low- and high-frequency coefficients. Finally, the fused image is constructed by the inverse NSCT with all composite coefficients.

4.6.1. Advantages

- Gives better information about curved areas.
- Gives directional information

4.6.2. Disadvantage

- High MSE value and low PSNR value.

S.NO	Paper Name	Fusion Technique	Advantages	Disadvantages
1.	Image Fusion of Digital Images	Simple Average	Simple in implementation	Resultant fused image is not clear
2.	Pixel-level Image Fusion using Wavelets and Principal Component Analysis	PCA	PCA is a tools which transforms number of correlated variable into number of uncorrelated variables, this property can be used in image fusion	Spectral degradation is present
3.	Pixel based and Wavelet based Image fusion Methods with their Comparative Study	DWT	Provide better signal to noise ratio	Less spatial resolution
4.	Medical image fusion by wavelet transforms modulus maxima.	DWT	A better preservation of component information. Fusion can be performed at different levels and bandwidths.	Not good at edge features. Limitations in the fusion of curved shapes.
5.	Medical image fusion based on discrete wavelet transforms	DWT	Simple and easy to understand and implement.	Some noise may introduce in fused image. Low accuracy for curved edges.
6.	Curvelet Fusion of MR and CT images.	Curvelet Fusion	Deal with images having curved shapes. Curved visual details are better. Image de-noising.	Limited directional information along vertical, horizontal and diagonal directions.
7.	Redundancy Discrete wavelet Transform and Contourlet Transform for multimodality medical image fusion with quantitative Analysis	DWT and Contourlet transform	Multi-resolution Localization Directionality	Computational Complexity High memory Consumption
8.	Medical Image Fusion based on Ripplet Transform Type-1.	Ripplet Transform	Capable of resolving 2D singularities. Representing image edges more efficiently.	Computational Complexity
9.	Biological Image Fusion using a NSCT based variable-weight method.	NSCT	Gives exact estimation Robust in Nature	Obtaining better results with MRI and PET images is difficult.

6. CONCLUSION

The fusion of multimodality medical images plays an critical and vital role in many clinical applications for they can support more comprehensive and accurate information than any individual source images. Earlier proposed methods suffer from the noise, artifacts and spectral degradation. The average methods lead to undesirable side effects such as reduced contrast. Pyramid method used for image fusion suffers from blocking artifacts and creates undesired edges, So these different methods shows various advantages as well as disadvantages and provides various results depending on the method to be used.

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