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Applications of Wavelet Transform To Multimodality Medical Image (PET&MRI) Fusion

[1]Harishbabu K M, [2]Mrs. S K Uma

[1]PG Student (CSE), [2]Asocc. Professor (dept of CSE), P.E.S. College of Engineering, Mandya, India
An Autonomous Institution under Visvesvaraya Technological University, Belgaum

Abstract: **This paper gives a view of the fusion of different modality images i.e. PET (Positron Emission Tomography) and MRI (magnetic resonance imaging) by integrating the DWT2 method. The decomposed coefficients of DWT2 (discrete wavelet transformation2) are applied to get fused image information. Before that, we decomposes DWT coefficients and averaging the approximate part of DWT coefficients and then reconstruct using inverse DWT to get the fussed image of two modalities MRI& PET. So that we get fused image of both anatomic, spectral information in one image, we used normal axial, and normal coronal, brain images as the three datasets for testing and fusing. Experimental results show that the performance of proposed fusion method is better than that of IHS+RIM fusion method in terms of spectral discrepancy (SD) and average gradient (AG). In fact, this method is superior to IHS+RIM method both visually and quantitatively.**

Keywords: **PET image, MR image, Image fusion, wavelet Transform2, GD, SD, PSNR, MES.**

1. INTRODUCTION

Various medical imaging modalities, such as magnetic resonance imaging (MRI), positron emission tomography (PET), Computerized Tomography (CT), have been developed and widely used for clinical diagnosis. In brain medical imaging, MR image provides high-resolution anatomical information in gray intensity, MRI is a medical_imaging technique used in radiology to investigate the anatomy and physiology of the body in both healthy and diseased brain image , MRI has a wide range of applications in medical diagnosis, it has an impact on diagnosis and treatment in many specialties although the effect on improved health outcomes is uncertain. The PET is a functional image displaying the brain activity without anatomical information. PET image is nuclear_medicine, functional imaging technique that produces a three-dimensional image of functional processes in the body. The object of image fusion is to achieve a high spatial resolution image with functional and anatomical information. Thus, fusing a MR image with a PET image into a single image with both anatomical structural and spectral information is highly desired.

Many methods for fusing PET and MR images have been proposed but have a serious side effect of color distortion. The proposed method is image fusion method based on discrete wavelet transform2 for brain regions with different activity levels. This method can generate very good fusion result by adjusting the structural information in the gray matter (GM) area, and then patching the spectral information in the white matter (WM) area. The performance of this fusion method is better than the performance of IHS+RIM fusion method in terms of two common assessment metrics including spectral discrepancy (SD) and average gradient (AG).

2. LITERATURE SURVEY

Image Fusion is used extensively in image processing systems. Various Image Fusion methods have been proposed in the literature to reduce blurring effects. Many of these methods are based on the post-processing idea. In other words, Image fusion enhances the quality of image by removing the noise and the blurriness of the image. Image fusion takes place at three different levels i.e. pixel, feature and decision. Its methods can be broadly classified into two i.e. Special domain fusion and transform domain fusion. Averaging, Brovery method, Principal Component Analysis (PCA), Are special domain methods. But special domain produce special distortion in the fused image .This problem can be solved by transform domain approach. The multi-resolution analysis has become a very useful tool for analyzing images.[1]Explained that the Image fusion is a process of combining multiple input images of the same scene into a single fused image, which preserves relevant information and also retains the important features from each of the original images and makes it more suitable for human and machine perception, in this paper, a novel region based image fusion method is proposed. In literature shows that region based image fusion algorithm performs better than pixel based fusion method. Proposed algorithm is applied on large number of registered images and results are compared using standard reference and no reference based fusion parameters. The proposed method is also compared with different methods reported in the recent literature. The simulation results show that our method performs better than other methods. [2]Has discussed a novel approach for the fusion of spatially registered images and image sequences, the fusion method incorporates a shift invariant extension of the discrete wavelet transform, which yields an over complete signal representation. The advantage of the proposed method is the improved temporal stability and consistency of the fused sequence compared to other existing fusion methods. We further introduce information theoretic quality measure based on mutual information to quantify the stability and consistency of the fused image sequence. [3]Explained that the main objective of image fusion is to create a new image regrouping the complementary information of the original images, the challenge is thus to fuse these two types of images by forming new images integrating both the spectral aspects of the low resolution images and the spatial aspects of the high resolution images. Compared to existing technologies reported in the literature the new proposed method is an innovative and unique technique in its own right.[4] has discussed that in this paper, the wavelet transforms of the input images are appropriately combined, and the new image is obtained by taking the inverse wavelet transform of the fused wavelet coefficients. An area-based maximum selection rule and a consistency verification step are used for feature selection. A performance measure using specially generated test images is also suggested. [5]Explained that this paper proposes an improved discrete wavelet framework based image fusion algorithm, after studying the principles and characteristics of the discrete wavelet framework. The improvement is the careful consideration of the high frequency sub band image region characteristic. The algorithms can efficiently synthesis the useful information of the each source image retrieved from the multi sensor. The multi focus image fusion experiment and medical image fusion experiment can verify that our proposed algorithm has the effectiveness in the image fusion. On the other side, this paper studies the quality assessment of the image fusion, and summarize and quantitatively analysis the performance of algorithms proposed in the paper. [6]Has focused on image fusion algorithm using hierarchical PCA, Authors described that the Image fusion is a process of combining two or more images (which are registered) of the same scene to get the more informative image. Hierarchical multiscale and multiresolution image processing techniques, pyramid decomposition are the basis for the majority of image fusion algorithms. Principal component analysis (PCA) is a well-known scheme for feature extraction and dimension reduction and is used for image fusion. We propose image fusion algorithm by combining pyramid and PCA techniques and carryout the quality analysis of proposed fusion algorithm without reference image.

3. PROBLEM STATEMENT

Image fusion is the process of integrating information from two or more images of the same position into a single image that contains more information and is more appropriate for visual. In the existing fusion approaches, the multiresolution fusion approaches have been widely used in the recent studies because of their efficiency and convenience, yet, their fusion results are usually limited by the number of decomposition layer and the selection of fusion rules. IHS transform and PCA technique can keep a better resolution, but, they also distort the spectral characteristics with different degree. The Brovey transform can also bring a disastrous fusion result. But in all existing fusion approaches color distortion problem arises from the change of the saturation during the fusion process. However, retina-inspired fusion method can just complement this shortcoming of spectral distortion in fusion process.

In our method we get better fused image with good visual effect of both anatomical and spectral information in a single image.

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4. WAVELET TRANSFORM BASED FUSION METHOD

As a powerful analytical tool, wavelet based methods have been developed for signal and image processing. The principle of wavelet image fusion is to get the best resolution without altering the spectral contents of the image. More clearly this principle is based on multiresolution analysis provided by wavelet Transform. The wavelets-based approach is appropriate for performing fusion tasks for the following reasons:

(1) It is a multiscale (multiresolution) approach well suited to manage the different image resolutions. In recent years, some researchers have studied multiscale representation (pyramid decomposition) of a signal and have established that multiscale information can be useful in a number of image processing applications including the image fusion.

(2) The wavelets transform (WT) allows the image decomposition in different kinds of coefficients preserving the image information.

(3) Such coefficients coming from different images can be appropriately combined to obtain new coefficients, so that the information in the original images is collected appropriately.

(4) Once the coefficients are merged, the final fused image is achieved through the inverse wavelet transform (IWT), where the information in the merged coefficients is also preserved.

5. METHODOLOGY OF THE PROJECT

The main objective is to design different from the regular simple DWT fusion method that performs wavelet decomposition with different levels for low- and high-activity regions, respectively, in the PET and MR brain mages. In addition, a novel adjustment for the pixel intensity in the non-WM area of high-activity region in the gray-level fused image will bring more anatomical structural information into the final color fused image. Spectral information patching in the white matter area of high-activity region will preserve more color information from PET image for the white-matter area.

A block diagram of proposed image fusion method is shown in Fig. 1.PET /MR image is decomposed by IHS transform into intensity component (I_P), hue component (H_P), and saturation component (S_P). There is a significant color difference between high- and low-activity regions in the PET image. The high-activity region is in red or yellow colors while the low-activity region is in blue color in a PET image. Thus, we use the “hue angle” information to differentiate high-activity region from low-activity region. The high-activity region is denoted by $I_{p,H}$ and the low-activity region is denoted by $I_{p,L}$. The corresponding high- and low activity regions in MR image, denoted by $I_{m,H}$ and $I_{m,L}$ respectively, can be easily obtained by mapping the two corresponding regions in the PET image into the MR image.

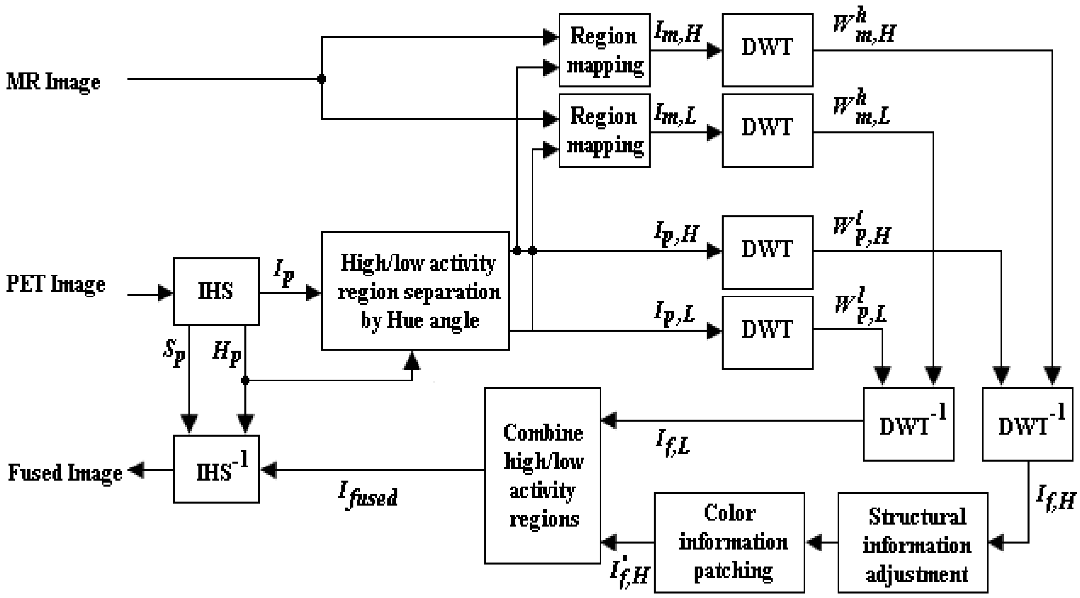


Fig.1. A block diagram of our proposed image fusion method

High-activity region carries more structural information while low-activity region carries more spectral information. Therefore, the high-activity region is decomposed by 4-level discrete wavelet transform2 to obtain more detailed structural information while the low-activity region is decomposed by 4- level wavelet transform to have better color preservation. Let $W^h_{m,H}$ ($W^h_{m,L}$) represent the wavelet coefficients in the high frequency bands for the high-activity (low-activity) region in the MR image. Let $W^l_{p,H}$ ($W^l_{p,L}$) represent the wavelet coefficients in the low-frequency bands for the high-activity (low-activity) region in the PET image. Then, we combine $W^h_{m,H}$ and $W^l_{p,H}$ into a complete set of wavelet coefficients and perform inverse wavelet transform to obtain a fused result, denoted by $I_{f,H}$, for the high-activity region. Similarly, by combining $W^h_{m,L}$ and $W^l_{p,L}$ into a complete set of wavelet coefficients and performing inverse wavelet transform, we can obtain a fused result, denoted by $I_{f,L}$, for the low-activity region.

In processing this, some anatomical structural information in the gray matter (GM) area of the high-activity region of the fused image $I_{f,H}$ is missing. This is because the intensity of the GM(gray matter) pixels neighboring to WM(white matter) area is pretty close to the intensity of the WM(white matter) pixels. For putting back the missing anatomical structural information, we use the following method to adjust the gray-level intensity of the GM pixels in $I_{f,H}$ so that the intensity difference between the GM pixels and WM pixels is large enough for visual observation.

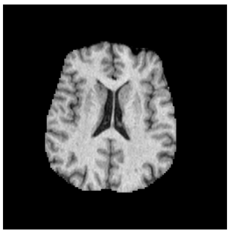
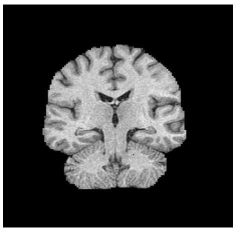
Let *Rw* be the WM area which can be segmented by using FCM (Fuzzy c-means algorithm). $B(x, y)$ is a 7 × 7 window centered at (x, y). $D_{avg}(x, y)$ is the average difference between the pixel's intensity of the I(intensity)-component of the original PET image and the pixel's intensity of the graylevel fused image for all WM pixels within window $B(x, y)$ i.e.

$$D_{avg}(x,y)=\frac{\sum_{(m,n)\in R_w\cap B(x,y)}\left(I_{p,H}(m,n)-I_{f,H}(m,n)\right)}{\left|R_w\cap B(x,y)\right|} \qquad (1)$$

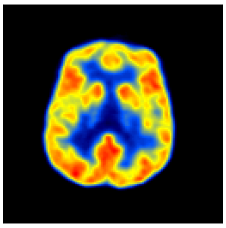
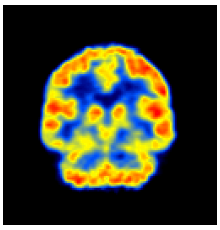
As mentioned before, the pixel intensity in $I_{f,H}$ is higher (brighter) than the pixel intensity in $I_{p,H}$. Therefore, the value $D_{avg}(x, y)$ in (1) is always negative. So we can lower down the intensity level for each non-WM pixel of the high-activity region in I-component fused image $I_{f,H}$ using (1), where the percentage of w is set to 50% or 70% in proposed method.

$$I_{f,H}(x,y)\leftarrow I_{f,H}(x,y)+w\times D_{avg}(x,y) \qquad (2)$$

On the other hand, for each pixel in the WM area of the high-activity region of I-component fused image, we replace $I_{f,H}(x, y)$ by $I_{p,H}(x, y)$ to keep less color distortion. We use $I^p_{f,H}$ to represent the high-activity region of the gray-level fused image after intensity adjustment by using (1) and spectral patching by using (2). Now we can combine $I_{f,L}$ with $I^p_{f,H}$ to form a new gray-level image I_{fused} as the I-component of the finally fused image. By taking I_{fused}, *Sp* (saturation-component of PET image), and H_p (hue-component of PET image) as the inputs for inverse IHS transform, we can obtain a finally fused image for PET and MR images.

(a) MRI normal axial **(b) MRI normal coronal**

(a) PET normal axial **(b) PET normal coronal**

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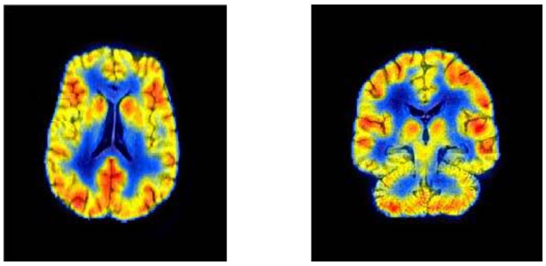
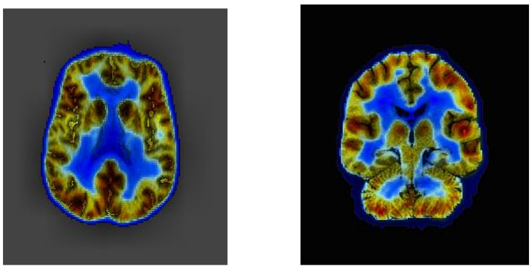


(a) HIS+RMI **(b) HIS+RMI**



(a)Dwt2 method **(b) Dwt2 method**

Fig 2. Two set of PET and MRI images and their corresponding fused results obtained by using HIS+RIM, and DWR2 method

6. EXPERIMENTAL RESULTS

The test data consist of two sets of brain images where each dataset consists of a color PET image and a high resolution MR image. The images in Dataset-1, Datasets-2, are normal axial, and normal coronal, images, respectively. The PET images and MR images for all three datasets as well as the fusion results by IHS+RIM, and DWT2 proposed methods are shown in Fig.3. In this study, we used three metrics for objective assessments. Firstly, the spectral discrepancy (SD) was used to measure the spectral quality of a fused image [7]. A good discrepancy means an acceptable fusion result. Secondly, average gradient (AG) was used to measure the spatial resolution of an image [7]. The larger the AG is, the higher the spatial resolution of the fused image has.

Table I and II show the performance comparisons between IHS+RIM and DWT2 method (with Dauchies 2 wavelet function provided by matlab). As we can see in Table I, DWT2 method have good SD values than IHS+RIM method in all three datasets. It is obvious that the fused image obtained from proposed method has better quality in colour as compared to the HIS+RIM method. Table II shows the performance comparisons based on AG metric. It is also obvious that proposed method is better than HIS+RIM method in terms of AG because our method always has higher AG values for all three datasets. We can also see that w = 0.7 has better performance than w = 0.5 in proposed method because the former can introduce more structural information from the MR image into the fused image.

7. CONCLUSION

In our method a new fusion method is used for fusing PET and MR brain images based on wavelet transform2 with structural information adjustment and spectral information patching. This method is different from the regular simple DWT fusion method in that our method performs wavelet decomposition with different levels for low and high-activity regions, In the PET and MRI brain images. In addition, adjustment for the pixel intensity in the non- WM area of high-activity region in the gray-level fused image will bring more anatomical structural information into the final colour fused image. Spectral information patching in the white matter area of high-activity region will preserve more colour information from PET image for the white-matter area. Experimental results demonstrated that our fused results for normal axial, normal coronal and Alzheimer's disease brain images have less colour distortion and richer anatomical structural information than those obtained from the IHS+RIM method visually and quantitatively. In proposed method we will also find the peak signal to noise ratio (PSNR) and mean square error (MSE) which will give quality measurement between the original image and fused image.

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In our method we also calculate the peak signal to noise ratio, which gives image quality in the percentage and we also calculate the mean square error cumulative squared error between the fused and the original image. We also used the contrast limited adaptive histogram equalization method to increase the brightness of the fused image.

Fusion method	Datasets-1	Datasets-2
IHS+RIM	7.7061	7.9031
Our method(w=0.5)	7.4111	6.7231
Our method(w=0.7)	2.4176	7.7181

Table I. Performance Comparison Based on Spectral Discrepancy between the Fused Image and the PET image

Fusion method	Datasets-1	Datasets-2
IHS+RIM	5.3603	6.2927
Our method(w=0.5)	5.4330	6.3670
Our method(w=0.7)	5.6281	6.3781

Table II. Performance Comparison Based on Average Gradient between the Fused Image and the MR image

8. ENHANCED WORK

In proposed method we compute PSNR and MSE values. This peak signal to noise ratio (PSNR) gives the ratio between images. This ratio is often used as a quality measurement between the original and a fused image.

The higher the PSNR, the better the quality of the fused or reconstructed image, PSNR and MSE are the two error metrics used to compare image quality. Equation to computing PSNR is as follows.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

Where, R is the maximum fluctuation in the input image data type.

Mean square error (MSR) Represent the cumulative squared error between the fused and the original image where as PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error, Equation to computing MSR is as follows.

$$MSE = \frac{\sum_{M,N}\left[I_1(m,n) - I_2(m,n)\right]^2}{M * N}$$

Where, M and N are the numbers of rows and columns in the input images

Error metrics	Datasets-1	Datasets-2
PSNR(w=0.5)	57.9194	64.1325
PSNR(w=0.7)	63.4634	58.2417

Table III: Performance Comparison based on peak signal to noise ratio of images

Error metrics	Datasets-1	Datasets-2
MSE(w=0.5)	0.10499	0.02510
MSE(w=0.7)	0.02929	0.09747

Table IV: Performance Comparison based on mean square error of images

Adaptive histogram equalization is a method which is used to improve the qualities of an image. They improve an image contrast and brightness characteristics, reduce its noise content or sharpen its details. This is an extension to traditional Histogram Equalization technique. It enhances the contrast of images by transforming the values in the intensity image I, it operates on small data regions (tiles), rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the specified histogram. The neighbouring tiles are then combined using bilinear interpolation in order to eliminate artificially induced boundaries.

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