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An Efficient Image Fusion of PET-MRI Using Wavelet Transforms

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ABSTRACT

In this paper, Image fusion of PET and MR brain images based on wavelet transform for low and high-activity brain image regions will be done. After wavelet decomposition and gray-level fusion the adjusting of anatomical structural information in gray matter (GM)area and patching the spectral information in white matter(WM) area are done by which the good fusion result can be obtained. Some datasets are used for testing and comparison of brain images. In terms of spectral discrepancy (SD) and average gradient (AG) the performance of proposed fusion method will be compared with IHS+RIM fusion method.

Keywords:- PET Image, MR Image, Image Fusion ,Wavelet Transform , Average Gradient(AG), Spectral Discrepancy(SD).

I. INTRODUCTION

The combination of two or more images to form one image is called image fusion. The fusion is to extract the features from all the original images and combined them to form fused images. The applications of image fusion are satellite image fusion, medical image fusion, remote sensing, and computer vision robotics. 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. MRI provides high-resolution anatomical information in gray intensity, while PET image reveals the biochemical changes in color without anatomical information. The complementary information that the images contain is reference to doctors so that a brain disease can be accurately diagnosed.

Many methods for fusing PET and MR images have been proposed. HIS substitution method is used in obtaining fused images with rich anatomical structural information which has side effect of color distortion [2, 3]. To generate fused images with less color distortion multiresolution methods were proposed but having the problem of missing detailed structural information. The combination of IHS transform and retina inspired models is proposed which has best performance in fusing PET and MR images. [7]

Good fusion result can be generated 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 our fusion method is better in terms of two metrics spectral discrepancy (SD) and average gradient (AG) than the performance of IHS+RIM fusion method.

II. DIFFERENT METHODS

a) Principal Components Analysis (PCA): PCA transformation is applied a on the low spatial resolution images, then first component is replaced by the high spatial resolution image. The fused images are obtained by applying an inverse PCA transformation on the new set of components

b) Intensity-Hue-Saturation Transformation (IHS): IHS transformation is applied on the low spatial resolution images, then the Intensity component is replaced by the high spatial resolution image. The fused images are obtained by applying a reverse HIS transformation on the new set of components.

c) High Pass Filter (HPF): where we integrate the low spatial resolution image through mathematical operations such as subtraction, addition, multiplication or ratios, with the spatial information obtained using High Pass type filtering on the high spatial resolution image.

d) Wavelet transformation (WT): based on pyramidal transformation, first the high resolution image is decomposed into a series of low resolution images, and then replaced by low resolution images with the original multispectral images with the corresponding resolution. We then apply an inverse pyramidal transformation to obtain the new fused images. [9]

III. PROPOSED METHODOLGY

The proposed image fusion method is represented by block diagram in Fig 1. The PET image is decomposed by IHS transform into intensity component(Ip), hue component(Hp) and saturation component(Sp).There is a color difference between high and low activity regions in PET image. The high activity region is in red or yellow colors while the low activity region in blue color in PET image. Hue angle information is used to differentiate high and low activity regions [1]. The high-activity region and low-activity region is denoted by $I_{p,H}$ and $I_{p,L}$ respectively. The corresponding high- and low activity regions in MR image, denoted by $Im_{,H}$ and $Im_{,L}$ respectively, can be easily obtained by mapping the two corresponding regions in the PET image into the MR image.

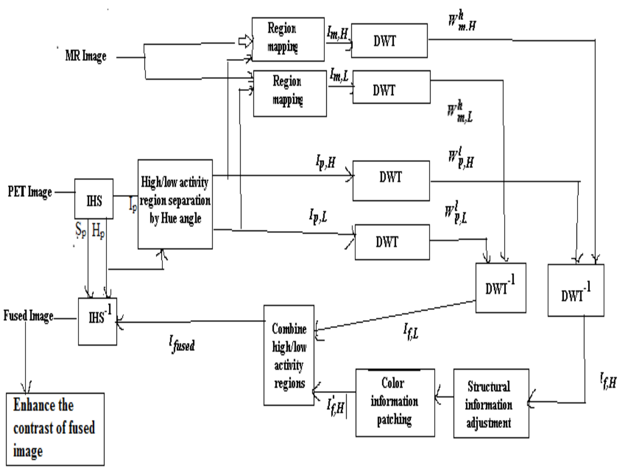

Fig 1.The block diagram of proposed method

High-activity region carries more structural information and is decomposed by 4-level wavelet transform. Low-activity region carries more spectral information and is decomposed by 3- level wavelet transform to have better color preservation. Wavelet coefficients of MRI and PET images are obtained , performing inverse wavelet transform to obtain a fused result denoted by $I_{f,H}$ and $I_{z,L}$ for high and low activity regions.

According to our observation, 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 pixels neighbouring to WM area is pretty close to the intensity of the WM pixels. To obtain back the missing anatomical structural information, we use the 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 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-component of the original PET image and the pixel's intensity of the gray level fused image for all WM pixels within window $B(x, y)$.

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

That is, (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 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 $I_{f,H}$, where the percentage *w* is set to 50% or 70% in our implementation.

$$I_{f,H}(x,y) = I_{f,h}(x,y) + w \times D_{avg}(x,y) \quad (2)$$

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 $I^{l}_{f,H}$, to represent the high-activity region of the gray-level fused image after intensity adjustment by using (1)and spectral patching (2).

Now we can combine $I_{f,H}$ with $I^{l}_{f,H}$, to form a new gray-level image I_{fused} as the I-component of the finally fused image. By taking I_{fused}, S_p(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. Later contrast of final fused gray scale image is enhanced by adapthisteq method which increases the AG and reduces the SD of image .

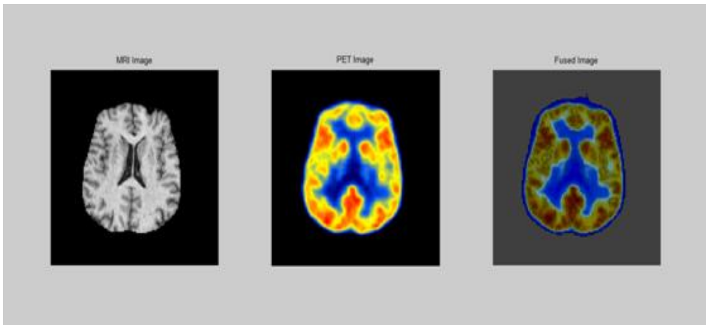

Fig 2. Fused image of PET-MRI

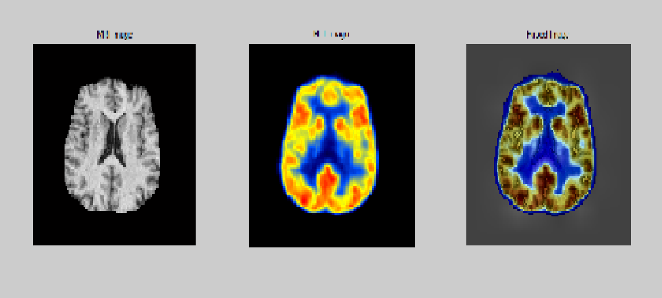

Fig 3. Fused image of PET-MRI after adapthisteq mtehod

IV. EXPERIMENTAL RESULTS

The PET images and MR images and fusion results for our proposed method are shown in fig 2 and 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 small 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 show the performance comparisons between IHS+RIM and our method. As we can see in Table I, our method has smaller SD values than IHS+RIM method. It is noted that the fused image obtained from our method has better quality in color as compared to the HIS+RIM method. Table II shows the performance comparisons based on AG metric. It is also obvious that our method is better than HIS+RIM method in terms of AG because our method always

Has higher AG values.

V. CONCLUSION

In this paper, a new fusion method for fusing PET and MR brain images based on wavelet transform with structural information adjustment and spectral information patching is proposed. Our 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, respectively, in the PET and MR brain images. 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. Experimental results demonstrated that our fused results for PET-MRI brain images have less color distortion and richer anatomical structural information than those obtained from the IHS+RIM method visually and quantitatively.

Table 1. Performance comparison based on spectral discrepancy

Fusion method	Data
IHS-RIM method	7.7061
Our method(w=0.5)	0.22781

Table 2. Performance comparison based on average gradient

Fusion method	Data
IHS-rim method	5.3603
Our method(w=0.5)	19.5908

Table 3. Performance comparison based on average gradient spectral discrepancy after using adapthisteq method for w=0.5

Metric	Before using adapthisteq method	After using adapthisteq method
AG	19.5908	30.2543
SD	0.22781	0.48248

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