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PET AND MRI BRAIN IMAGE FUSION USING REDUNDANT WAVELET TRANSFORM

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Abstract— In our project, we are using Redundant Wavelet Transform for fusion of low activity and high activity regions of both PET and MRI images. Here we generate the fused images of the anatomical structural information and the spectral information, in the gray matter (GM) and White matter (WM) areas respectively. These images are then decomposed by using redundant wavelet transform (RWT). Positron Emission Tomography (PET) images show the biological changes in color without any anatomical information, whereas the Magnetic Resonance Imaging (MRI) produces high resolution images with the anatomical information. Previously images were fused was done by using IHS substitution method, IHS+RIM fusion method and using DWT (discrete wavelet transform).Our proposed method is superior to the previously methods implemented both visually and quantitatively. The PSNR and the MRSE of the proposed system is better than the previous system.
The proposed method was described, functionally tested and implemented on MATLAB R2010a tool. Implementation results could provide better clarity of the brain disease.
Keywords: Image fusion, PET, MRI, DWT, RWT

I. INTRODUCTION

Image fusion is the technique of combining two or more images; the resultant fused image contains more detailed information. The images to be to be fused are measured by using different sensors for the single image. The main aim of fusion is to combine multisensor, multi view and multi temporal information's of the same image, to get better information about the image. Image fusion has numerous applications: it's used in remote sensing, astronomy, and in the field of medical imaging like MRI, CT[4] etc, in the military
And surveillance areas fusion of multi sensor images of visible and infrared images is used.
Various methods were proposed in the past for fusion of PET and MRI image. The IHS substitution method had a drawback of color distortion. To overcome this drawback, a new method called IHS+RIM (Retina Inspired Model)[3] was proposed.

In this paper, using Redundant Wavelet Transform (RWT) we have fused PET and MRI images, for brain activities with different levels. By combining the structural information in grey matter (GM) area and the spectral information in the white matter (WM) area, we get better fusion result.

II. FUSION METHOD

A. Types of fusion methods

There are two methods for fusing[5] of the images:

- Spatial method
- Transform Domain fusion

Various spatial methods are : averaging method, IHS (Intensity Hue saturation), PCA[1], and Borvey transform.

The advantage of the IHS method is it provides better visual effect and image will have high spatial quality. But, the limitation of this method is color distortion is produced with respect to the original image. To overcome this drawback we have used wavelet transform method.

Wavelet analysis was introduced to improve the seismic signal analysis. The property of good localization and irregularities make them suitable for analysis of continuous signals. There was transformation from short time Fourier analysis to new better algorithms, in order to detect and analyze the abrupt (sudden) changes in the signals. Wavelets can be seen as a complement to the Fourier decomposition method. A wavelet can be simply defined as a small wave, which decays quickly. Thus, wavelets are oscillatory functions with finite duration, which have zero average value. Wavelets have finite energy and are preferred for analysis of transient signals.

B. Wavelet transform

Wavelet analysis was introduced to improve the seismic signal analysis. The property of good localization and irregularities make them suitable for analysis of continuous signals. There was transformation from short time Fourier analysis to new better algorithms, in order to detect and analyze the abrupt (sudden) changes in the signals. Wavelets can be seen as a complement to the Fourier decomposition method. A wavelet can be simply defined as a small wave, which decays quickly. Thus, wavelets are oscillatory functions with finite duration, which have zero average value.

Wavelets have finite energy and are preferred for analysis of transient signals. Wavelets were considered to be constructed from the translations and dilations of a single function, which was known as" Mother Wavelet $\psi(t)$".

Wavelet, defined by the equation,

$$\Psi_{a,b}(t) = (1/\sqrt{|a|})\, \psi((t-b)/a), \qquad a,b \in R,\ a \neq 0 \quad (1)$$

Where,

a -is the scaling parameter, which measures the degree of compression.b- is the translation parameter, that determines the time location of the wavelet.

If $|a| < 1$, wavelet $\psi_{a,b}(t)$ is the compressed version of the mother wavelet, and corresponds mainly to higher frequencies. If $|a| > 1$, then the wavelet $\psi_{a,b}(t)$ has larger time widths than $\psi(t)$ and corresponds to the lower frequencies. This shows that the wavelets have time widths adapted to their frequencies and was the main reason for the success of the Morlet wavelets in the analysis of the time-frequency signals and signal processing methods.

The Wavelet transform decompose the image into four bands of frequencies that is Low-Low, Low-High, High-High and High-Low bands respectively. Here Low-Low band contains the average information of the image and the other band contains the directional information, which is due to spatial orientation in the other three bands (LH, HH, and HL). Higher bands correspond to the higher absolute values of wavelet coefficients. These values correspond to the features such as, edges, lines etc.

III. PROPOSED METHOD

The proposed method as shown in the Fig.1 uses RWT for fusion of PET and MRI images. The process performed in the block diagram Fig.1 is as follows:

The first step is IHS [2] transform is applied to the MRI and PET images. The IHS image preserve color than the RGB image, and thus the conversion of the image is performed. This separates the high activity region and the low activity regions. The high activity region denoted by the red or yellow color, which carry more structural information, while the low activity region is denoted by blue which carry spectral information. The MRI image shows the anatomy of the brain and the PET image shows the functionality of the body, such as blood flow and tissue functionality. Thus the high activity region has more of structural information. The high activity region is decomposed by 4-level RWT, in order to obtain more structural information. The low activity region is decomposed by 3-level RWT to have better color preservation.

The RWT transform is applied on the coefficients of the high and low activity regions. Since RWT is used, none of the pixels are missed during the decomposition of the image, thereby retaining the same number of samples in the output as in the input.

The difference between the pixels intensity of the I-component of the original PET image and the pixels intensity of the grey level fused image is known as Davg. The white matter (WM) area is segmented using fuzzy K-means algorithm(FKM) as shown in Fig. 7. In the proposed system fuzzy-K means (FKM) algorithm[8] is used instead of Fuzzy C means(FCM), because FCM involves complex calculations. The time constraint is reduced by using FKM algorithm and clusters are formed. Since segmentation is an important step in image fusion.

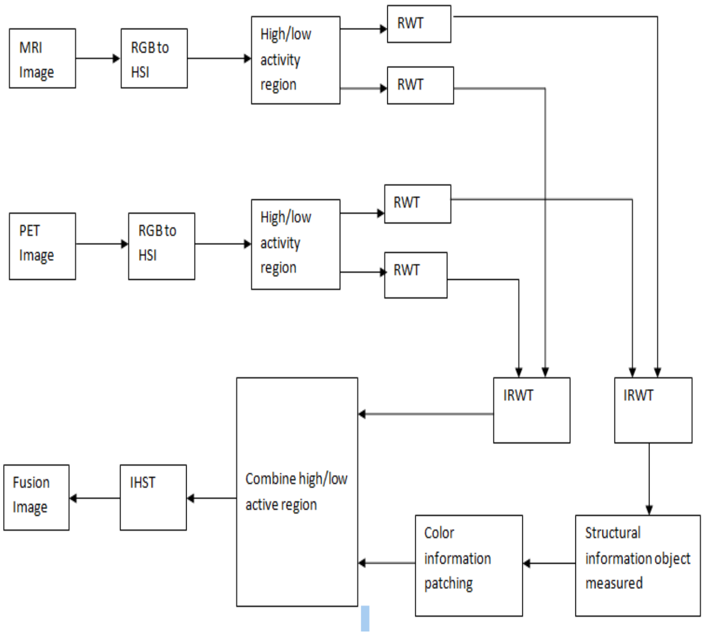

Fig.1. Block diagram of proposed method

Here, segments are formed based on the similarity in the gray intensity level of the images. The color information is patched and the high and low activity regions are fused. The inverse IHS transform is applied on the final fused image. Thus, the fused image is a color image and evidences the formation of clots fig 8.
RWT is an undecimated version of DWT. The disadvantage of DWT is lack of translation invariance. To overcome this limitation we use RWT. Translation invariance is achieved by removing the downsamples and upsamples in DWT. In RWT [7] only upsamplings is performed.

$$Ws(a,b) = \int f(t) \frac{1}{\sqrt{a}} \varphi^*(\frac{x-b}{a})dt \qquad (2)$$

$$Ws(j,k) = \int f(t) 2^{-\frac{j}{2}} \varphi^*(\frac{x-k}{2^j})dt \qquad (3)$$

Advantages of RWT are it provides greater functionality and robustness. It increases the numerical stability. It helps in feature detection and motion estimation. Because RWT is shift invariant it performs better.

IV. EXPERIMENTAL RESULTS

The images of PET and MRI from the dataset are taken, and these images are subjected to IHS transform, RWT and IRWT and final result is fused. The average gradient of the proposed system is better than the existing system, which shows the fused image has better clarity, thereby making diagnosis of the disease easier. The MRI-PET machine is shown in fig 9.The resultant images obtained are as follows.

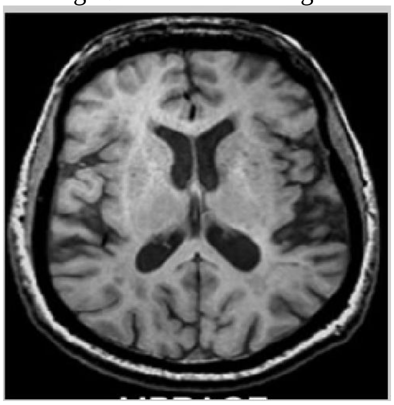

Fig. 2 MRI image

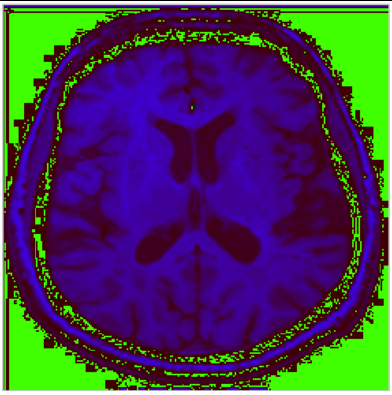
Fig. 3 hsi of MRI image

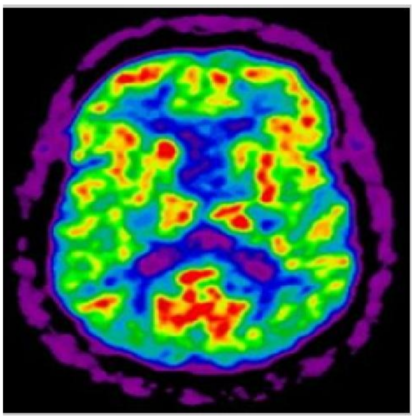
Fig.3 PET image

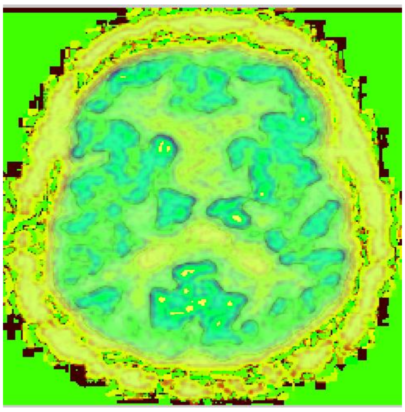
Fig.4 hsi of PET image

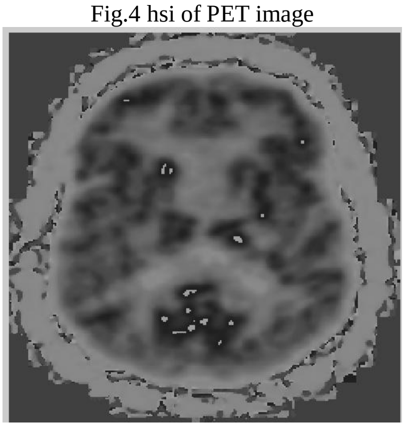
Fig. 5 inverse RWT of intensity

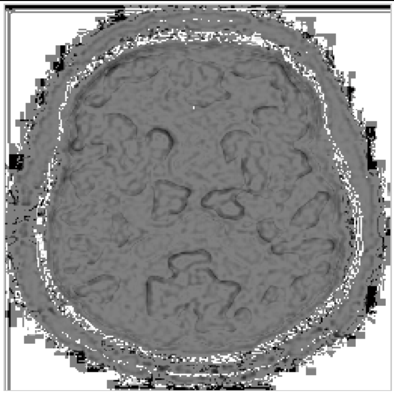

Fig. 6 inverse RWT of saturation

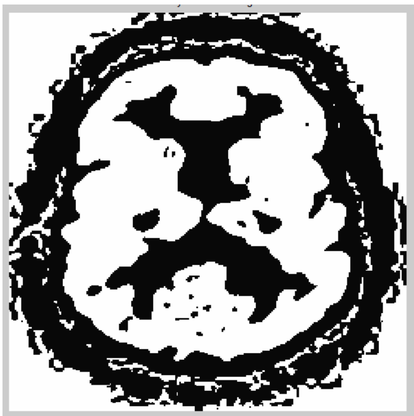

Fig. 7 fuzzy c-means image

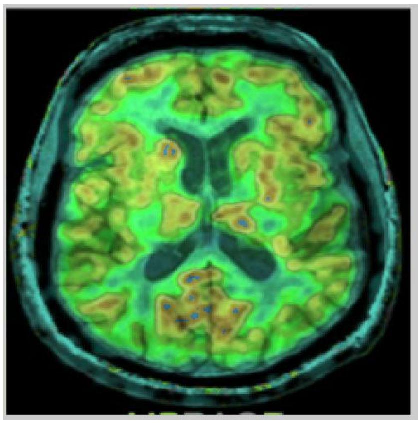

Fig. 8 fused image

Parameter	Dataset 1	Dataset 2	Dataset 3
PSNR	35.32	33.497	24.44
Entropy	8.65	9.665	9.286

Table 1: Performance comparison for different dataset of images based on PSNR and entropy

Fusion Methods	Dataset 1	Dataset 2
IHS-RIM method	5.3603	6.2927
fusion using DWT	5.4759	6.4355
fusion using RWT	8.061	5.71

Table 2: Performance comparison based on average gradient

Fig 9: MRI-PET machine

V. CONCLUSIONS

In this paper, the proposed method fuses PET and MRI image, by using RWT which adjust the spectral and structural information. The brain images of this method have less color distortion and richer anatomical structural information compared to the IHS+RIM method. Since RWT is used, the numbers of samples are retained throughout the process.

The PSNR, entropy and average gradient are the parameters that are measured in this implementation. The MRI-PET technology combines the delicate anatomical and structural information of the body in the MRI image with the sensitivity and functionality of the PET images. Thus ,the final fused image has gray matter in the MRI projected onto the PET image. This technology can be used for early detection of tumors, for detecting genetic disorders and neurological defects.

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