IMAGE FUSION OF PET AND MRI IMAGE USING R^2I^2HS ALGORITHM

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ABSTRACT: Image fusion has become a widely used tool for increasing the interpretation quality of images in medical applications. The acquired data might exhibit either good functional characteristic (such as PET) or high spatial resolution (such as MRI). The MRI image shows the brain tissue anatomy and contains no functional information. The PET image indicates the brain function and has a low spatial resolution. Hence, the image fusion task is carried out to enhance the spatial resolution of the functional images by combining them with a high-resolution anatomic image. A perfect fusion process preserves the original functional characteristics and adds spatial characteristics to the image with no spatial distortion. The intensity-hue-saturation (IHS) algorithm and the retina-inspired model (RIM) fusion technique can preserve more spatial feature and more functional information content, respectively. The presented algorithm integrates the advantages of both IHS and RIM fusion methods with Relighting to improve the functional and spatial information content. Visual and statistical analyses show that the proposed algorithm significantly improves the fusion quality in terms of: entropy, mutual information, discrepancy, and average gradient; compared to fusion methods including, IHS, Brovey, discrete wavelet transform (DWT), à-trous wavelet and RIM

Keywords: Magnetic Resonance Imaging(MRI), Computed Tomography(CT), Positron Emission Tomography(PET), Retina-Inspired Model(RIM), Inner Plexiform Layer(IPL)

I.INTRODUCTION

Medical imaging is divided into structural and functional systems. MRI and CT (computed tomography) provide high-resolution images with structural and anatomical information. PET (positron emission tomography)and SPECT(single-photon emission computed tomography) images provide functional information with low spatial resolution. In recent years, the success of PET-MRI imaging in the clinical field has triggered considerable interest in noninvasive functional and anatomical imaging. The limited spatial resolution in PET images has often resulted unsatisfactory in morphological analysis. Combining anatomical and functional tomographic datasets provide much more qualitative detection and quantitative determination in this area . In this paper, we assume PET images are shown in pseudo- color, and therefore, treat them as color images. Image fusion is the process of integrating information from two or more images of an object into a single image that is more informative and appropriate for visual perception or computer analysis. The purpose of image fusion is to decrease ambiguity and minimize redundancy in the output while maximizing the relative information specific to an application. Prospective algorithms for the fusion are generally classified into three categories:(1) Substitution methods, such as IHS and PCA (Principal Component Analysis) fusion methods.(2) Arithmetic combination, such as Brovey, SVR (Synthetic Variable Ratio) and RE (Ratio Enhancement).(3) Multi-resolution fusion methods, which introduce spatial features from the high-resolution images into the multispectral color) images, such as RIM, wavelets, Gaussian Laplacian pyramid techniques .The multi-resolution fusion techniques have been discussed widely in the recent studies because of their advantages over the other fusion techniques. The IHS technique has been most commonly used in the practical applications , but, this technique can lead to spectral distortion in the results . It is desirable that the fusion process preserves the original color information of PET image and the spatial characteristics of MRI image as much as possible , in the sense that only the complementary spatial information existing in MRI data be introduced into the PET. To avoid the weak points of the IHS fusion technique and those of the retina-inspired technique, an IHS and RIM integrated fusion approach has been proposed in this study. The results show that the proposed algorithm significantly improves the fusion quality in terms of entropy, mutual information, discrepancy, and average gradient compared to other fusion methods. This paper builds on the research formerly presented in and its main contributions are as follows:

- Presenting a comprehensive theoretical basis behind the design of our algorithm.
- Describing the RIM fusion method.
- Explaining the IHS fusion method and its ability and deficiency.
- Proposing the use of a model based on integrated IHS and RIM to improve the fusion performance.

II.RETINA-INSPIRED MODEL:

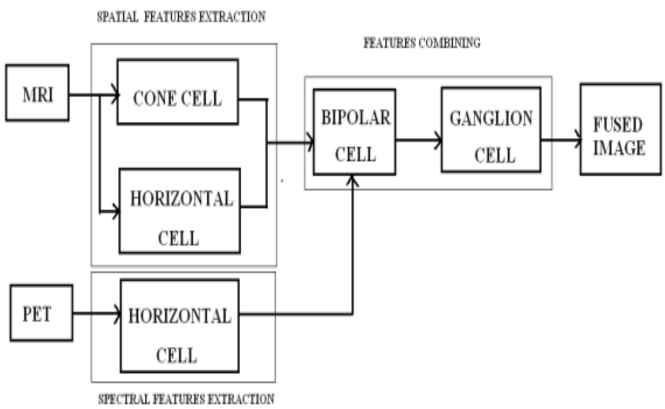

Figure 1. RIM Algorithm

The photonic visual perception begins with the scene captured by cone and rod photoreceptors. The cones are highly sensitive to color, and the rods are sensitive to low light intensity, which is not required for the current research, however, the cones are significant. Image luminance is transmitted by the cone layer to the downstream retina and cortical layers. From the cone to ganglion layers, a pipeline of cellular layers can be identified. A pipeline can be classified into two functionality categories:the outer plexiform layer (OPL) and the inner plexiform layer (IPL). OPL properties are generated by the synaptic triad, which is composed of interconnected cells :

The cone cells form a transduction and regularization processing. The transduction converts luminance into electrochemical potentials at the downstream layers. The regularization process consists of a low-pass filtering. The cone cells are defined in terms of their functions (spectral sensibilities: red, green, and blue colors).

III.IHS FUSION TECHNIQUE:

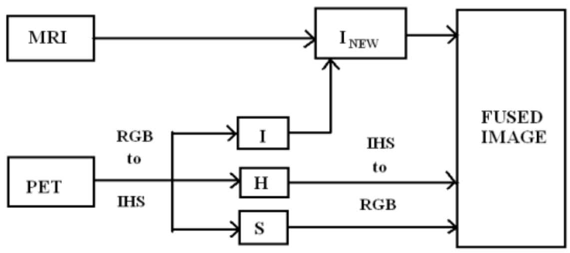

Figure 2. IHS Algorithm

The IHS transform converts a multispectral image with red, green and blue channels (RGB) to intensity, hue and saturation independent components. The intensity displays the brightness in a spectrum, the hue is the property of the spectral wavelength, and the saturation is the purity of the spectrum. This transform may be used for the fusion of multi-sensor images . The fundamentals of IHS fusion are:
(1) Aligning the input multispectral image to the high-resolution image;
(2) Transforming the input multispectral image from RGB to IHS color space;
(3) Substituting the intensity component with the high-resolution image;
(4) Transforming the new substituted IHS components into RGB color space. This process leads to a fused and enhanced spectral image. The diagram of this procedure is shown in general HIS based is explained by the following equations:

$$\begin{pmatrix} I \\ v1 \\ v2 \end{pmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & \frac{-2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \end{bmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix},$$

$$H = \tan^{-1}\left(\frac{v1}{v2}\right),$$

$$S = \sqrt{v1^2 + v2^2}.$$

Where v1 and v2 are the transitional values in the above equations.

The inverse transform is:

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{-2}{\sqrt{6}} & 0 \end{bmatrix} \begin{pmatrix} I \\ S\sin(H) \\ S\cos(H) \end{pmatrix}$$

Triangular spectral model is another type of commonly used IHS transform, where can be depicted as:

$$I = \frac{R+G+B}{3}$$

$$\begin{cases} H = \frac{G-B}{3I-3B}, & S = \frac{I-B}{I}, \quad \text{if } B < R, G \\ H = \frac{B-R}{3I-3R} + 1, & S = \frac{I-R}{I}, \quad \text{if } R < B, G, \\ H = \frac{R-G}{3I-3G} + 2, & S = \frac{I-G}{I}, \quad \text{if } G < R, B \end{cases}$$

The inverse IHS Transforms is shown below:

$$\begin{cases} R = I(1+2S-3SH), \quad G = I(1-S+3SH), \quad B = I(1-S), \\ \qquad \text{if } B < R, G \\ R = I(1-S), \quad G = I(1+5S-3SH), \quad B = I(1-4S+3SH), \\ \qquad \text{if } R < G, B \\ R = I(1-7S+3SH), \quad G = I(1-S), \quad B = I(1+8S-3SH), \\ \qquad \text{if } G < R, B \end{cases}$$

These two IHS fusion models are used to evaluate the proposed model. Furthermore, the IHS triangular model participates in the proposed integrated model.

IV.COMBINATION OF IHS AND RIM ALGORITHM:

The IHS fusion technique produces high spatial intensity images. However, due to the low correlation between the PET intensity image and the fused images, the spectral distortion isconsiderable . The retina-inspired image fusion can preserve more spectral information than other conventional fusion methods . However, the spatial details in the retina-inspired- fusion results are often different from the MRI image, which introduces spatial distortion into the results. To improve the IHS and the retina-inspired fusion techniques, and to overcome the deficiencies of the two methods, an integrated fusion method is proposed in this paper. To attain a smooth combination of spectral and spatial features, the proposed method employs the IHS triangular model to integrate the PET spectral (color) information with the MRI spatial detail information . This fusion process generates a new high resolution color image. The new image contains both the spatial detail of the MRI source image, and the color detail of the PET source image, simultaneously. In the first stage, the PET image is transformed into the IHS-triangular-model components.

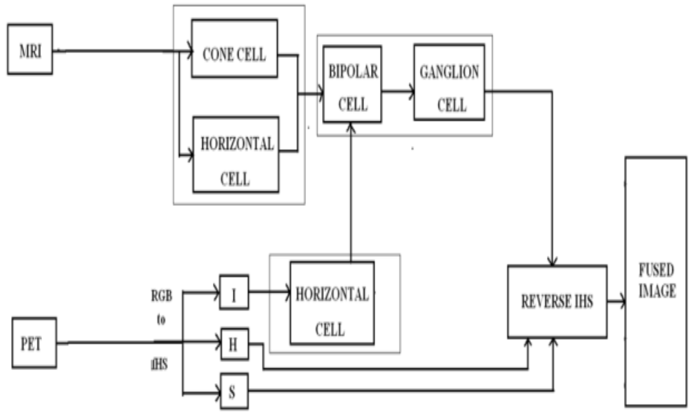

Figure 3. Image fusion

The PET image should be aligned to the MRI image in advance. In the second stage, histogram matching is applied to match the histogram of the MRI image with the PET-intensity component. The third stage is performed by combining the new MRI (called New Pan) and original PET-intensity component, using retina-inspired fusion method. In this stage a new intensity image is obtained, which contains the same spatial detail of the original MRI and has the same intensity distribution to the original PET. Ultimately, this process is completed by inverse IHS transform of the new intensity and the old hue and saturation components back into RGB space.

V.R^{2}I^{2}HS ALGORITHM:

RELIGHTING:

The normal PET and the MRI image is first undergoing a preprocess known as Relighting. In this concept the MRI image is first subjected to this Relighting concept and in parallel, this process is also applied to the PET image. This relighting is just increasing the concentration of the images only to a small extent. By doing so, the hidden tissues are now somewhat better in their visible capacity.

International Journal of Contemporary Research in Computer Science and Technology (IJCRCST) e-ISSN: 2395-5325
Volume1, Issue 6 (September '2015)

VI.IMPLEMENTATION OF R^2I^2HS ALGORITHM:

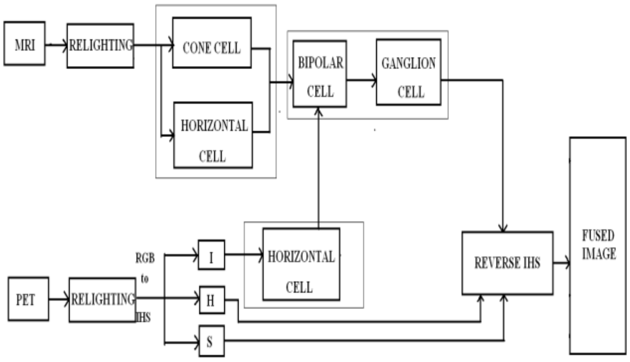

Figure 4. R^2I^2HS Algorithm

The IHS fusion technique produces high spatial intensity images. However, due to the low correlation between the PET intensity image and the fused images, the spectral distortion is considerable . The retina-inspired image fusion can preserve more spectral information than other conventional fusion methods. However, the spatial details in the retina-inspired- fusion results are often different from the MRI image, which introduces spatial distortion into the results. To improve the HIS and the retina-inspired fusion techniques, and to overcome the deficiencies of the two methods, an integrated fusion method is proposed in this paper. To attain a smooth combination of spectral and spatial features, the proposed method employs the IHS triangular model to integrate the PET spectral (color) information with the MRI spatial detail information . This fusion process generates a new high resolution color image. The new image contains both the spatial detail of the MRI source image, and the color detail of the PET source image, simultaneously. In the first stage, the PET image is transformed into the IHS-triangular-model components. The PET image should be aligned to the MRI image in advance. In the second stage, histogram matching is applied to match the histogram of the MRI image with the PET-intensity component. The third stage is performed by combining the new MRI (called New Pan) and original PET-intensity component, using retina-inspired fusion method. In this stage a new intensity image is obtained, which contains the same spatial detail of the original MRI and has the same intensity distribution to the original PET

VII.INVERSE IHS:

After the fusion technique is applied, the fused images will be obtained in the form of Intensity Hue Saturation Value. This can be returned back to their colored format by only using the inverse IHS technique. The Inverse IHS is done using the following formula,

IF B<R, R=I(1+2S-3SH), G=I(1-S+3SH), B=I(1-S).

IF R<G, R=I(1-S), G=I(1+5S-3SH), B=I(1-4S+3SH)

IF G<R, R=I(1-7S+3SH), G=I(1-S), B=I(1+8S-3SH)

B-blue, R-red, G-green, I-intensity, H-hue, S-saturation, Thus by using the above formula the corresponding colored image of the fused MRI and PET image is obtained. Thus after the fusion of both the images using various algorithm, they are all compared theoretically and practically in order to view the best fusion technique.

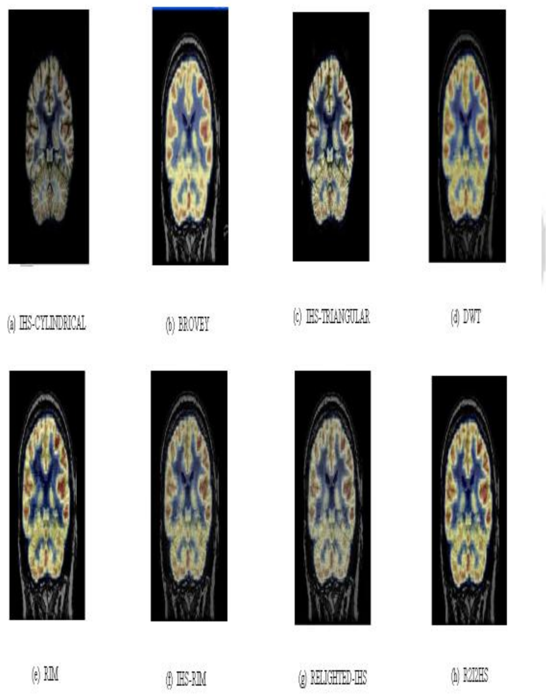

Figure 5. Fused Image

VIII. CONCLUSION:

In this paper, we proposed a new method for PET and MRI images fusion. We assume PET images are shown in pseudo-color, and therefore, treat them as color images. The PET produces images with suitable color and low spatial resolutions, while MRI provides appropriate spatial resolution with no color information content. The algorithms and fusion results of the most popular IHS fusion and the RIM fusion technique are reviewed to find the weak points of both fusion techniques and use their potencies. The RIM image fusion usually can preserve more color information than the IHS method but it preserves less spatial information content. The presented algorithm integrates the advantages of both IHS and RIM fusion methods to improve the color and spatial information content. In the proposed fused images the color information was least distorted, the spatial details were as clear as the original MRI, and the integration of color and spatial features was normal. The statistical analyses tools such as entropy, mutual information, discrepancy, and average gradient are demonstrated that the proposed algorithm did considerably increase spatial information content and reduce the color distortion compared to the counterpart fusion methods. Those statistical assessment findings agree with the visual analysis. An advantage of this method, similar to retina-inspired fusion method, is that it can perform in any aspect ratio between images' pixels and does not require resampling process.

IX. FUTURE ENHANCEMENT:

This current proposed algorithm solves the problem related to spatial resolution as well as spectral resolution. Even though the performance of the proposed algorithm is in advance with the previous existing algorithms, their improvement is not in a higher variation when compared with the previous one. Thus , an algorithm with a higher positive variation than the previous existing algorithm is going to be proposed.

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