

A COMPARISON OF MRI AND PET IMAGES FUSION BASED ON YCBCR AND IHS COLOR SPACES

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Abstract

Image fusion is a process in which two or more images from different sources or of various states are merged to create a single image in order to increase desired information of the images, decrease ambiguity, and eliminate repeated information. Fusion of high spatial resolution images such as MRI image with high spectral resolution images such as PET image is a case in point. A proper fusion technique adds spatial information to the final image without obliterating spectral information. Among all available techniques for image fusion, color space based fusion, which can generate appropriate results, is widely used. Analysis and comparison of YCbCr color space based fusion and IHS based fusion methods are provided in this paper. Visual and quantitative evaluations indicate that YCbCr technique compared to IHS method performs better in preserving spectral information. However, IHS method yields better image fusion with regard to spectral information preservation.

Keywords: Image fusion, IHS (Intensity, Hue, Saturation), YCbCr color space, MRI (Magnetic resonance imaging), PET (Positron emission tomography).

1. Introduction

Medical imaging methods have diverse features and structures, and the output image of each method can include various types of information. Generally, medical imaging methods are divided into two major groups: 1) methods in which the structure and anatomy of the tissue under investigation are of utmost importance. These methods are highly capable of spatial resolution, for example MRI and CT images. 2) Methods in which recording of the function and activity of the tissue is important. In such images, tissue activities are described artificially through allocation of a spectrum of particular colors.

Consequently, resultant images of these methods contain spectral information, but structural and spatial information presented in such images are significantly weak, for example Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT).

Precise diagnosis and analysis frequently require images of both aforementioned methods simultaneously. As a result, images that provide spatial and spectral information simultaneously can be worthwhile in medical diagnosis and analysis. However, due to scientific and practical constraints, providing such

images is out of reach. On the contrary, through image fusion methods, it is possible to extract desired information from each image and put it into a single one [1-5]. For instance, spatial information of the MRI and CT can be extracted and added to the spectral information of the PET and SPECT in a way that the spectral information of the images is not destroyed. There are various methods of fusing high spectral resolution images with high spatial resolution ones including:

Replacement methods, such as IHS and PCA [6-7]

Statistical methods, such as Brovey, SVR (Synthetic Variable Ratio), and RE (Ratio Enhancement) [8]

Multi resolution methods, such as wavelet Transformation and Retina Inspired Model [9-11]

Spatial and spectral features are frequently impaired during the fusion process; this can lead to complications in diagnosis and analysis process. Therefore, a desirable fusion method results in minimum obliteration in spatial and spectral information [11]

This paper is organized as follows: in section 1, an introduction to the subject is presented. IHS fusion and YCbCr fusion methods are discussed in sections 2 and 3, respectively. Quantitative evaluation approaches are introduced in section 4. An example with two sets of images is employed to evaluate fusion methods in section 5. Fusion results are assessed through quantitative approaches in section

6. Finally, conclusions are drawn in section 7.

2. IHS based fusion method

IHS is fusion method based on color space. IHS color space maps three particles RED, GREEN, and BLUE from RGB color space onto three particles INTENSITY (I), HUE (H), and SATURATION (S), respectively. Where 'I' represents light intensity, 'H' represents wavelength, and 'S' shows purity level. Equations 1 to 4 define transformation from RGB to IHS color space [6].

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ -\sqrt{2}/6 & -\sqrt{2}/6 & -2\sqrt{2}/6 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} \quad (2)$$

$$H = \tan^{-1} \frac{V_2}{V_1} \quad (3)$$

$$S = \sqrt{V_1^2 + V_2^2} \quad (4)$$

Where V_1 and V_2 are interface variables, and apply S and H features into mapping.

Separating the factor associated with spatial information (I) from factors associated with spectral information (S, H), fusion is conducted through replacing spatial and spectral factors in the input image. In this transformation, I, H, and S factors of the RGB image are separated from each other, and spatial information with high resolution (one-color image) replaces spatial information 'I'. It is noteworthy that H and S factors are first

normalized (homogenized) in terms of sampling, and then inverse transformation processes are conducted [6].

In order to fuse PET and MRI images through aforementioned method, first, images are stabilized and registered. Then, PET, a colored image, is mapped onto IHS color space, and the information of the light intensity (I) is replaced by the information of the MRI images. Subsequently, through an inverse transformation from IHS to RGB, the final image is achieved. Figure 1 presents the block diagram of the fusion process via IHS transformation method [6, 12].

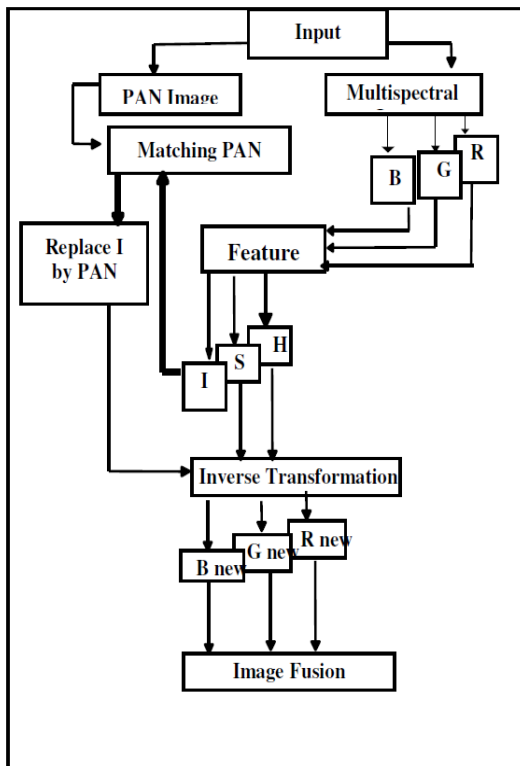


Fig.1. Block diagram of the fusion via IHS transformation [12]

3. YCbCr color space based fusion method

In this color space, information associated with the image is stored in two forms, namely Luminance, and Chrominance. Luminance information is stored in the form of 'Y'; Chrominance information is saved in the forms of 'Cb' and 'Cr' particles. 'Cb' defines the deviation of the blue component from the reference value, and Cr represents the deviation of the red component from its reference value [13]. Figure (2) shows Cb and Cr curve for the Y values of 0, 0.5 and 1.

The relationship between YCbCr color space and RGB color space can be expressed through the following equations [13]:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112.000 \\ 112.000 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (5)$$

Images in RGB color space do not have proper and effective performance due to transformation and signal storage redundancy; however, by employing YCbCr color space, luminance component of the image can be extracted and saved in a higher resolution format, or it can be transferred in a higher bandwidth. Two color components, Cb and Cr, can be employed to decrease the bandwidth, compress sampling, or improve the efficiency of the system.

YCbCr color space is capable of preserving luminance information of the image. This feature can play an important role in quality improvement of the output image in the fusion process of multi sensor images in which a multi-spectral image is

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fused with a panchromatic (single-spectral) image (black and white).

In order to fuse PET and MRI images using YCbCr method, first, image registration is conducted. Then, the following steps should be taken:

1. Transformation of color space of PET image from RGB color space to YCbCr color space
2. Extracting Y, Cb, and Cr components of the image
3. Replacing spatial information of the MRI image by Y component of PET image and generating a new image (As MRI image includes only spatial

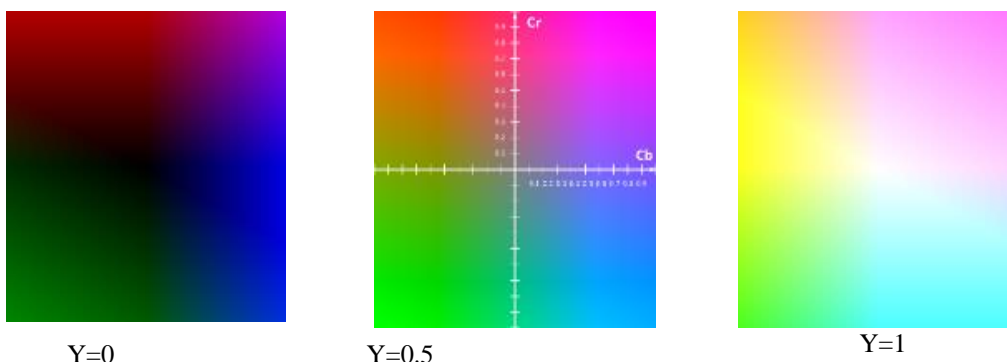


Fig.2. Cb and Cr curve for the Y values of 0 and 0.5

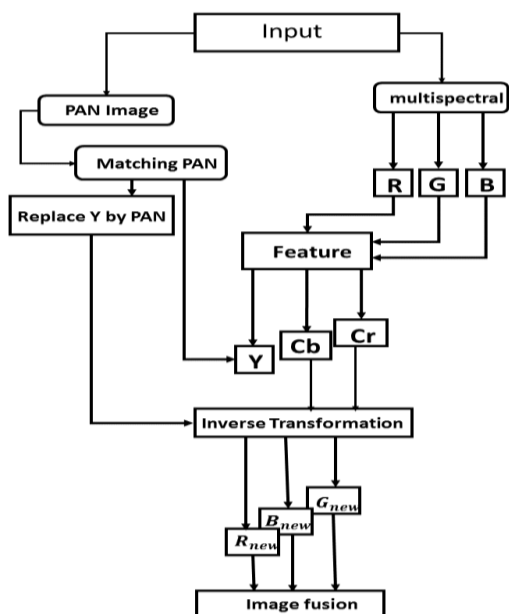


Fig.3. The block diagram of YCbCr color space based fusion method

information, whole information of the MRI image replaces Y information of the PET image.)

4. Transformation of YCbCr color space to RGB color space

The block diagram of the YCbCr color space based fusion is presented in figure (3).

Since spatial information is well preserved in YCbCr color space, we expect the spatial information to be transferred with high accuracy.

4. Results and discussion

A database including PET and HI-resolution MRI images is employed to evaluate the discussed fusion methods. Spatial resolution of the MRI and PET images is 256*256 pixels. PET image coincides fully with the MRI image. Images were downloaded from Harvard university website.

Cerebral images are classified in three groups including coronal, sagittal, and transaxial. Visual evaluation of the resultant images of IHS and YCbCr fusion methods reveals that spectral information is preserved better in IHS method compared to YCbCr method. Although information obliteration exists in IHS method, it is much lower compared to that of YCbCr fusion method. On the other hand, spatial information is well preserved in YCbCr fusion method compared to IHS method.

In this research, four quantitative evaluation approaches are employed to assess the performance of YCbCr and IHS fusion methods.

4.1. Correlation Coefficient

Correlation coefficient is a general criterion for evaluating spectral and spatial quality of the images. This criterion measures the correlation between the fused image and the reference one. The ideal value of the correlation coefficient is one. Correlation coefficient for two images, A and B, is defined as:

$$CC(A, B) = \frac{\sum_{mn}(A_{mn}-\bar{A})(B_{mn}-\bar{B})}{\sqrt{(\sum_{mn}(A_{mn}-\bar{A})^2)(\sum_{mn}(B_{mn}-\bar{B})^2)}} \quad (6)$$

Where \bar{A} and \bar{B} represent the mean of matrix of images A and B, respectively. Both m and n are the position of the pixels [14].

4.2. Spectral Discrepancy

Spectral discrepancy is a criterion to measure spectral quality of images. Spectral discrepancy for a fused image F and a reference image L is defined as [14]:

$$D_k = \frac{1}{P \cdot Q} \sum_{x=1}^P \sum_{y=1}^Q |F_k(x, y) - L_k(x, y)|$$

$$k = R, G, B \quad (7)$$

4.3. Average Gradient

Average Gradient is a criterion to measure spatial resolution of the image, and it shows the resolution (clarity) of that image [14].

$$ag_k = \frac{1}{(P-1)(Q-1)} \times \sum_{x=1}^{P-1} \sum_{y=1}^{Q-1} \sqrt{\frac{\left(\frac{\partial F_K(x,y)}{\partial x}\right)^2 + \left(\frac{\partial F_K(x,y)}{\partial y}\right)^2}{2}} \quad (8)$$

Both x and y are positions of the pixels of the images. P and Q are the dimensions of the images, which are assumed to be 256*256 in this paper.

**4.4. Root Mean Square Error
 (RMSE)**

RMSE shows the variation between the result of the fusion of a band and the original band. A smaller value of RSME means that the spectral information of the original band is preserved during the fusion process. RMSE is defined as [14]:

$$E_k = \sqrt{\frac{\sum_{i=1}^N \sum_{j=1}^M (f_k(i,j) - b_k(i,j))^2}{NM}} \quad (9)$$

Results of the correlation method of the fused image with MRI image via YCbCr fusion method has higher coefficient amount compared to IHS method; that is, YCbCr method presents an acceptable

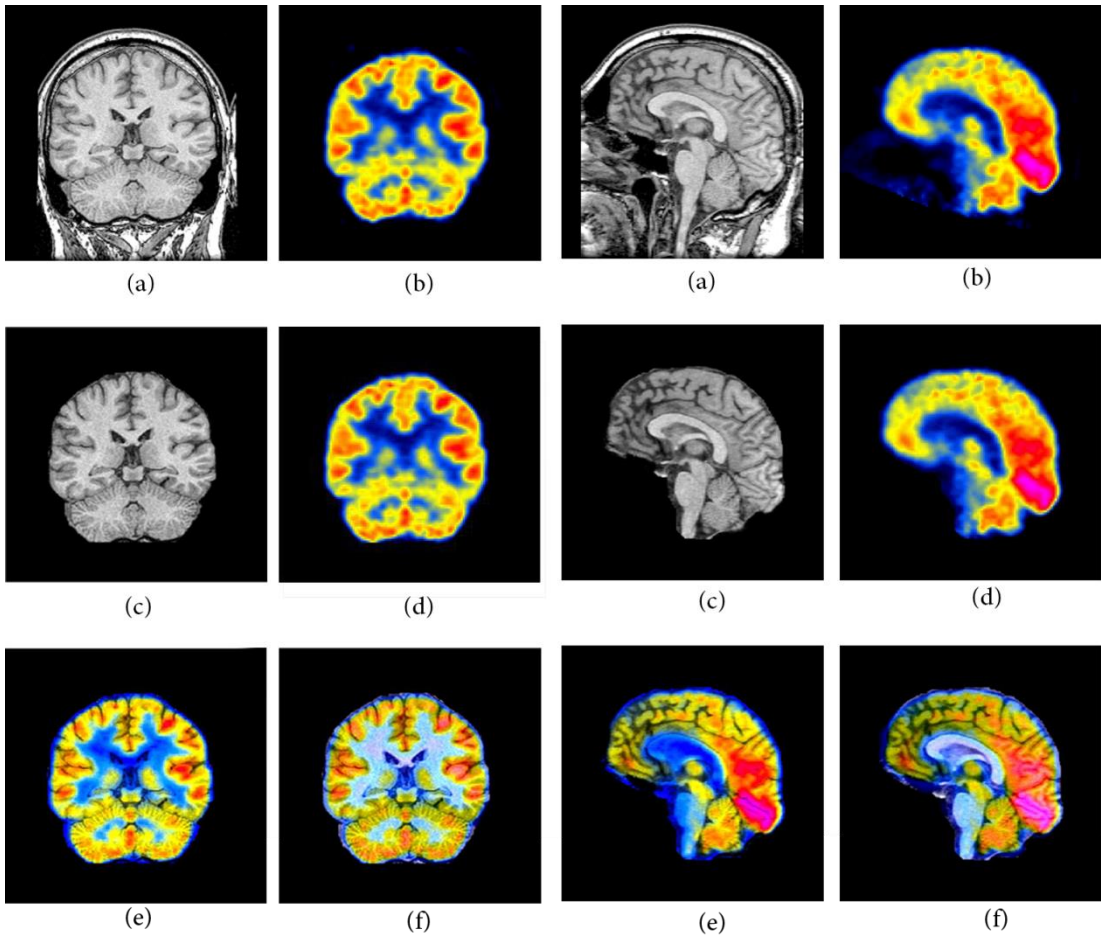


Fig.4.: Coronal section view of MRI and PET images (a and b), MRI and PET images prepared for fusion (c and d), resultant image of the IHS fusion (e), resultant image of the YCbCr fusion (f)

Fig.5.: Sagittal section view of MRI and PET images (a and b), MRI and PET images prepared for fusion (c and d), resultant image of the IHS fusion (e), resultant image of the YCbCr fusion (f)

performance in preserving spatial information. However, the results of the correlation method of a fused image with PET image through IHS method is better compared to YCbCr method, which indicates the fact that IHS method can perform better in preserving spectral information. Calculations of RMSE method confirm the results of correlation method.

In YCbCr method, the fused image has a small value of error with the MRI image, which shows that this method is better in preserving spatial information. The fused image through IHS method shows a small value of error with the PET image, which means this method can preserve spectral information better. The results of the spectral discrepancy method, which was conducted separately on each band, also confirms that IHS method performs better in preserving spectral information. The results of the Average Gradient method also revealed that YCbCr method shows a better performance in preserving spatial information.

Conclusion

The purpose of image fusion is not only to increase desired information but also to decrease ambiguity and eliminate repeated information. As PET images include weak spatial information, they make medical diagnosis difficult. Fusion of a multi-spectral PET image with an MRI image, which has high spatial resolution, can

eliminate such difficulties. In this paper, fusion methods based on color spaces of IHS and YCbCr were discussed and evaluated. Quantitative evaluations using RMSE, spectral discrepancy, average Gradient, and Correlation Coefficient were conducted on the resultant images of both methods. Visual and quantitative evaluations indicate that YCbCr fusion method preserves more spatial information than IHS, and it has higher spatial resolution. On the other hand, IHS preserves more spectral information, and it has a higher spectral resolution.

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Table 1

Quantitative assessment results for Coronal and Sagittal section images using correlation, RMSE, spectral Discrepancy, and Average Gradient methods.

| | Coronal | | Sagittal | |
|------------------------------|---------|--------|----------|--------|
| | YCbCr | IHS | YCbCr | IHS |
| Correlation MRI | 0.9990 | 0.9359 | 0.9975 | 0.9183 |
| Correlation PET | 0.8975 | 0.9551 | 0.8738 | 0.9290 |
| RMSE MRI | 0.0210 | 0.1125 | 0.0193 | 0.1047 |
| RMSE PET | 0.1479 | 0.0955 | 0.1500 | 0.1109 |
| Spectral Discrepancy RED | 0.0788 | 0.0287 | 0.0744 | 0.0355 |
| Spectral Discrepancy Green | 0.0842 | 0.0513 | 0.0873 | 0.0512 |
| Spectral Discrepancy BLUE | 0.0414 | 0.0382 | 0.0520 | 0.0478 |
| Spectral Discrepancy average | 0.0681 | 0.0394 | 0.0712 | 0.0448 |
| Average gradient R | 0.0228 | 0.0216 | 0.0183 | 0.0157 |
| Average gradient G | 0.0241 | 0.0240 | 0.0202 | 0.0191 |
| Average gradient B | 0.0264 | 0.0254 | 0.0192 | 0.0197 |
| Average gradient total | 0.0244 | 0.0237 | 0.0192 | 0.0182 |

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