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Statistical Measurements of Multi Modal MRI – PET Medical Image Fusion using 2D – HT in HSV color Space

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Abstract

The goal of image fusion is to obtain large amount of information into a single image with more quantitatively and qualitatively. The image fusion can be applicable in various fields like multi-focus, multi-modal medical, satellite etc. This paper proposed statistical measurements of Multimodal MRI-PET medical image fusion using 2D Hartley transform (HT) in HSV color space. This proposed method was discussed with two different modalities of medical images like MRI (Magnetic Resonance Imaging) and PET (Positron Emission Tomography) and also discussed with five steps. Initially the PET color image is converted into HSV channels. Second step is MRI and V component of PET image are divided into 8*8 blocks and then apply 2D Hartley transform on each block of two input images. Third step is compute variance of each block of two images and then select best blocks. Fourth step is applying inverse 2D HT and all blocks are arranged into single image i.e. new V component. Finally concordination of New V component, H, S to get HSV image and then convert HSV to RGB to obtain final fused image with more accurate. The result shows the importance of the proposed image and this is superior to existing methods like DFT along with Smooth, Hartley along with Smooth, Hartley along with Mean, DFT along with Mean and DCT along with Smooth. The evaluation parameters such as Mean, Standard Deviation and Gradient plays a major role in image fusion for testing the quality.

Keywords: Multi modal Medical images, Medical Image Fusion; 2D HT, HSV color Space, Statistical measurements (Mean, STD, Variance).

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1. Introduction

Image fusion is one of the emerging technologies to get maximum content of data from different images into single resultant image. The image fusion can be applicable in many fields like multi-focus, multi-temporal, multi - modal medical, satellite, etc.. In all fields: medical image fusion plays a role on medical images and is the process of merging different individual medical images into single medical image i.e. fused image [1]. The fused image having more information than the individual input images [2]. In this paper, MRI-PET medical image fusion has been used. The MRI (Magnetic Resonance imaging) [3] image provides soft tissue information from the different organs in human body and also high spatial resolution. The other medical image is PET (Positron Emission Tomography) [4], it provides functional information and low spatial resolution because PET images are color images. The physician to examine the MRI-PET images of a patient for disease identification and better clinical treatment [5]. These two images are provides limited information. To obtain more accurate information into a single image we go for medical image fusion. Generally image fusion can be implemented in 2 domains: (1) time domain [6], (2) Frequency domain [7]. In spatial domain, spatial distortions will be occurred during the fusion process. The spatial domain drawbacks are overcome by using frequency domain techniques. There are several frequency domain techniques like DFT [8], DCT [9], Hadamard [10], etc..

The rest of the paper is arranged by following manner. In section 2 , we discuss about the 2D Hartley transform and HSV color space. We discuss the proposed method in section 3. Finally section 3 and 4, we discuss about the results and conclusion parts.

2. 2D Hartley Transform

The Hartley Transform (HT) was introduced by the scientist Hartley. This was the alternative method to the Fourier Transform. In DFT, it can be produced complex outputs but in Hartley transform, which can produce real outputs and also less memory usage because it does not produce the complex outputs. For simplicity and complexity, this method is superior to some of the transform techniques [11].

The mathematical representation of Hartley Transform is

$$H(p,q) = \sum_{j=1}^{M}\sum_{l=1}^{N} h(j,l)cas\left(\frac{2\pi}{N}(jp+lq)\right) ----2D-HT \tag{1}$$

$$h(j,l) = \frac{1}{M\times N}\sum_{p=1}^{M}\sum_{q=1}^{N} H(p.q)cas\left(\frac{2\pi}{N}(jp+lq)\right) --2D-IHT \tag{2}$$

Where $cas(p) = \cos(p) + \sin(p)$

In the above two equations where h (j, l) represents the input image, *H (p, q)* indicates the Hartley transform coefficients image, and M*N are the size of the image.

2.1. HSV color Space

In this modal, the components are H (Hue), S (Saturation) and V (Value). These components are specifying the color. Alternatively this model is also called as HSB [12]. The conversion of RGB to HSV color model using following steps:

1. Calculate the max and min value of RGB component. $k = k_{\max} - k_{\min}$ (3)
2. The saturation value is $S = \begin{cases} \frac{k}{k_{\max}} & for k_{\max} > 0 \\ 0 & otherwise \end{cases}$ (4)
3. The V stands for value is given as $V = \frac{k_{\max}}{r_{\max}}$ (5)
4. The normalized Hue is in the range [0, 1]. $H = \frac{1}{6}\times\begin{cases} (H' + 6) & for H' < 0 \\ H' & otherwise \end{cases}$ (6)

Where $$H' = \begin{cases} B' - G' & if \quad R = k_{max} \\ R' - B' + 2 & if \quad G = k_{max} \\ G' - R' + 4 & if \quad B = k_{max} \end{cases} \quad (7)$$

And perform reverse operation to obtain RGB image from HSV model by following steps:

1. Calculate $H' = (6 \times H) \bmod 6$ (8)

2. Calculate

$$x = (1 - S) \times V$$
$$y = [1 - (S \times (H' - \lfloor H' \rfloor))] \times V \quad (9)$$
$$z = \left[1 - (S \times (1 - H' - \lfloor H' \rfloor))\right] \times V$$

3. Based on $\lfloor H' \rfloor$ value make a branch is as follows:

$$\text{Switch } \left(\lfloor H' \rfloor\right)$$
$$\begin{aligned} &case \quad 0 : (V, z, x) \\ &case \quad 1 : (y, V, x) \\ &case \quad 2 : (x, V, z) \\ &case \quad 3 : (x, y, V) \\ &case \quad 4 : (z, x, y) \\ &case \quad 5 : (V, x, y) \end{aligned} \quad (10)$$

4. The value can be rounded off as follows:

$$\begin{aligned} R &= \min(round(R' \times 256), 255) \\ G &= \min(round(G' \times 256), 255) \\ B &= \min(round(B' \times 256), 255) \end{aligned} \quad (11)$$

3. Proposed Method

In this paper, the proposed is a statistical measurements of Multi-modal medical image fusion using 2D HT in HSV color Space. In image fusion, image registration plays a major role that means both images are having same dimensionality.

This Multi-modal MRI-PET medical image fusion was checked and tested by two different modalities of the medical images i.e. MRI and PET. MRI gives only anatomical information and PET gives functional information of human organ. To get maximum content of information we are using image fusion operation.

The proposed method steps are as follows:

1. Read MRI (in1) and PET (in2) images for fusion process. These two images are having same dimensionality.
2. PET is the color image. So PET image is converted into HSV color space then we can get three different channels like H (Hue) , S (Saturation), V(value).
3. The MRI (in1) and Brightness value (V) images are divided into 8*8 blocks.
4. Apply 2D Hartley Transform (2D HT) on each block of two images to get coefficients. After 2D HT, compute variance for each block of two image coefficients (MRI and V images) and select the highest values of blocks and apply inverse 2D HT to get fused blocks. The variance is calculated by the given formula:

Variance:

Variance the statistical measurement and it shows the quality [13]:

$$\mathrm{var} = \frac{\sum_{p=1}^{P} \sum_{q=1}^{Q} \left(in1(i,j) - \overline{IN} \right)^2}{M \times N} \tag{12}$$

5. After that all fused sub blocks are arranged into single image to obtain new Brightness value of PET image.
6. Final concordination of new brightness value (V) of PET image, H and S to get HSV image
7. Final fused medical image can be obtained by conversion from HSV to RGB for disease analysis.

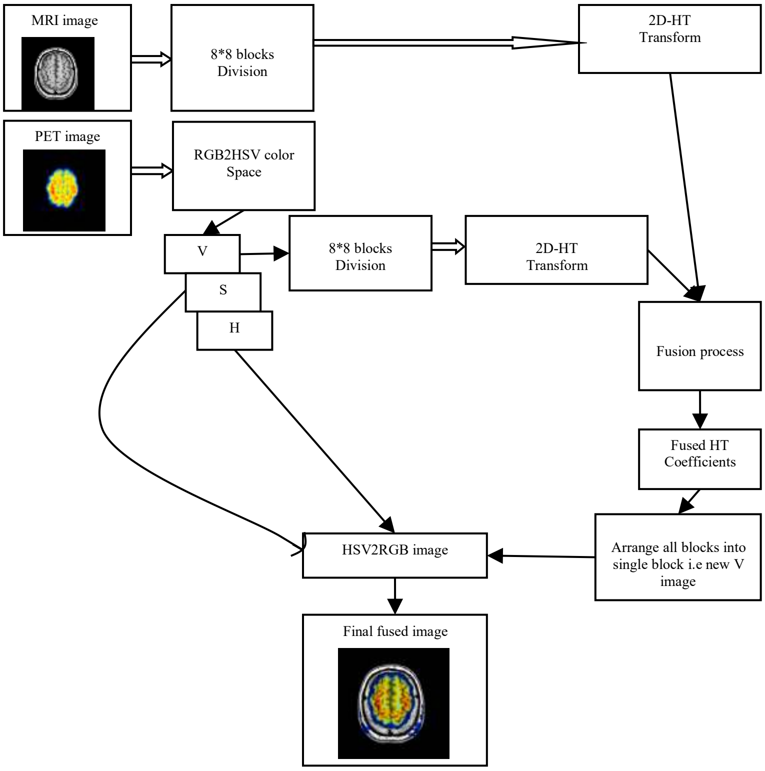


Fig. 1. . Multi-modal MRI-PET medical image fusion using 2D HT.

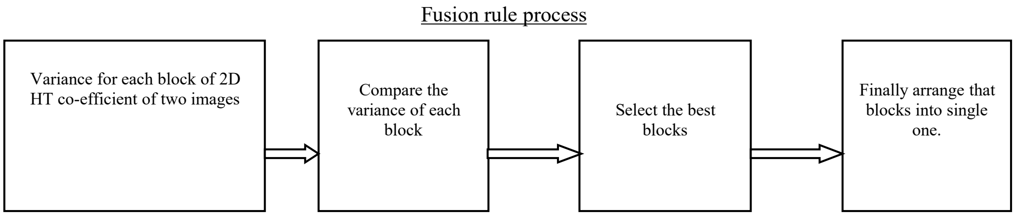


Fig. 2. Fusion rule process.

4. Experimental Results

This section is related to experimental results on statistical measurements of multi-modality medical image fusion using the block processing of 2D HT in HSV color space. This proposed method was tested by two different contents of medical images. The dimensionality of MRI is 256*256 and PET image is 256*256*3. The proposed method is superior to some of the transform domain techniques with statistical measurements like DCT+ Smooth, DFT+Mean, DFT+Smooth, Hartley+ Mean, Hartley+ Smooth. The quality metrics also shows the bitterness of the proposed method with respect to Mean, Standard Deviation and Gradient.

The Fig 3 and Fig 4 shows the proposed fused image with comparisons of Existing methods and table 1 show the quality metric values with comparison of existing techniques. In this proposed method Fig 5 represents the graphical representation of values.

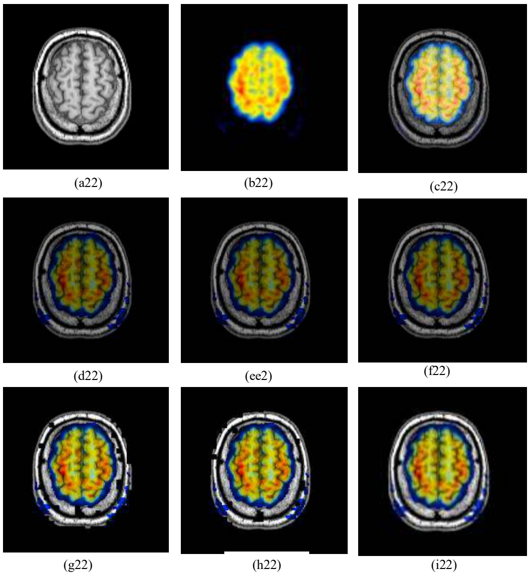


Fig. 3. Medical images Data set 1 (a22) & (b22) are MRI- PET images , (c22) Ground tooth image, (d22) DCT+Smooth method, (e22) Hartley+Smooth, (f22) DFT+Smooth, (g22) Hartley+mean, (h22) DFT+Mean, (i22) Proposedmethod.

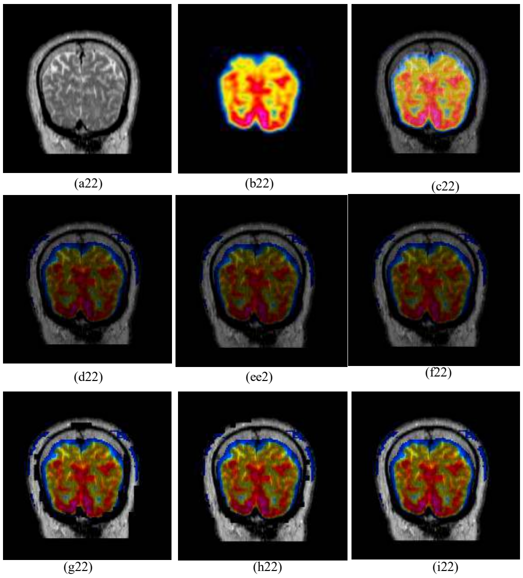


Fig. 4. Medical images Data set 2 (a22) & (b22) are MRI- PET images , (c22) Ground tooth image, (d22) Hartley+Smooth, (e22) DCT+Smooth method, (f22) DFT+Smooth, (g22) Hartley+mean, (h22) DFT+Mean, (i22) Proposedmethod.

4.1. Mean [14]

$$\mu = \frac{1}{P1 \times Q1} \sum_{p1=1}^{P1} \sum_{q1=1}^{Q1} fus(p1,q1) \tag{13}$$

It shows the quality. This value is highest means quality of fused image is good.

4.2. Standard Deviation (STD) [14]

$$\sigma = \left\{ \frac{1}{P1 \times Q1} \sum_{p1=1}^{P1} \sum_{q1=1}^{Q1} \left[fus(p1,q1) - \mu \right]^2 \right\}^{\frac{1}{2}} \tag{14}$$

It is used to estimate the changes in intensities in image. The STD value is high means fused image is good.

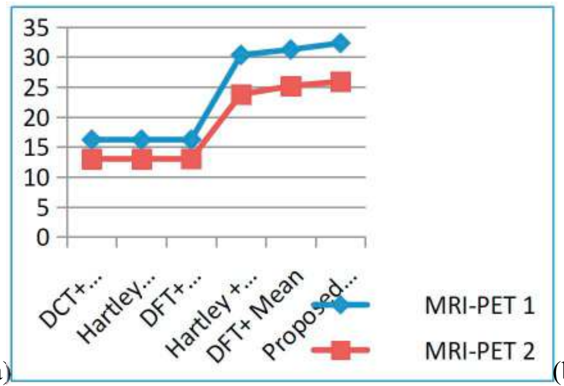
4.3. Average Gradient (AG) [15]

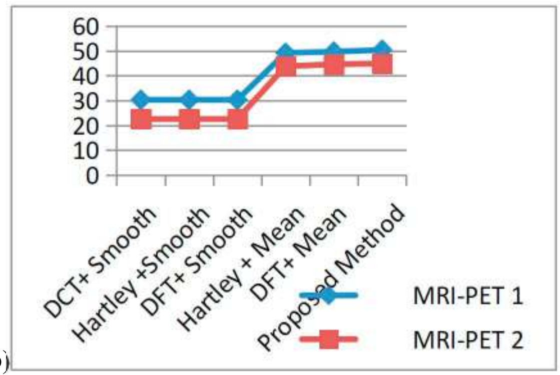
$$AG = \frac{1}{P1 \times Q1} \frac{\sum_{p1=1}^{P1} \sum_{q1=1}^{Q1} \sqrt{\left[Fus(p1,q1) - Fu(p1+1,q1)\right]^2 + \left[Fus(p1,q1) - Fu(p1,q1+1)\right]^2}}{\sqrt{2}} \tag{15}$$

The parameter used for clearness of the fused image. The AG value is high means fused image is good.

Table 1. Evaluation of fused image w.r.to quality metrics

Fusion images	Fusion Techniques	Evaluation parameters		
		Mean	STD	Gradient
MRI-PET Data set 1 (Fig 3)	DCT+ Smooth	16.2084	30.3035	4.0477
	Hartley +Smooth	16.2087	30.3035	4.0477
	DFT+ Smooth	16.2203	30.3210	4.0568
	Hartley + Mean	30.3519	49.2912	4.7921
	DFT+ Mean	31.2431	49.7594	4.9489
	Proposed Method	**32.3315**	**50.4860**	**5.0910**
MRI-PET Data set 2 (Fig 4)	Hartley +Smooth	13.0064	22.5364	2.5281
	DCT+ Smooth	13.0068	22.5365	2.5283
	DFT+ Smooth	13.0248	22.5601	2.5356
	Hartley + Mean	23.7914	43.8452	4.8607
	DFT+ Mean	25.1578	44.6614	5.0228
	Proposed Method	**25.9156**	**44.9582**	**5.0510**

(a)


(b)


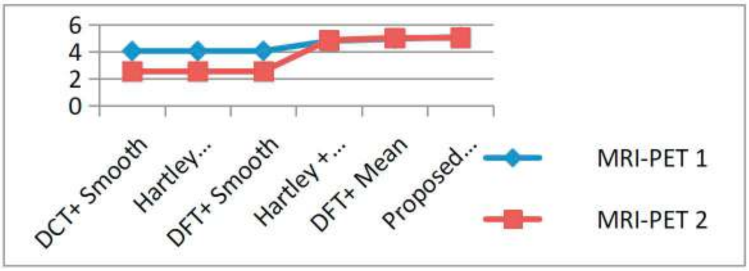
(c) 

Fig. 5. Graphical representation of Proposed method w.r.t. (a) Mean, (b) STD and (c) Gradient.

5. Conclusion

In this paper, we propose of multi modal medical images fusion using 2D HT in HSV color space. Initially PET image is converted into RGB to HSV color space. After that calculation of variance of block-based 2D HT coefficients of both MRI and V of PET images and then select best blocks and then apply inverse 2D HT to get new blocks of fused coefficients. The all fused blocks are arranged into single image to obtain new Brightness value (new V) of PET image. Finally to obtain fused image, after concordination of (new V component, H and S) and also conversion of HSV to RGB color space. In this paper, the proposed method is checking on different sets of multi modal medical images and also various evaluation parameters (Mean, STD and Gradient). The proposed method produce the accurate results over the existing techniques with respect to metrics in table 1.

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