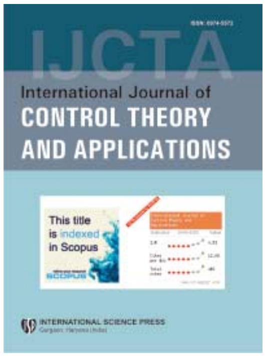

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Feature Level based Multimodal Medical Image Fusion with Hadamard Transform

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Abstract: Image fusion is combining multimodal complementary image's information into single image. This resultant image inherits all the details of individual images. This idea leads to propose novel algorithm for fusion process. The work stars with MRI (Magnetic resonance imaging) & SPET (structural positron emission tomography) scan medical images data. Initially these images are transformed into coefficients with Hadamard transform. The transformed coefficients are divided into '*b*' number of equal blocks. Each block feature values are computed with standard Deviation, Entropy, Visibility, Spatial frequency & correlation to perform the fusion process. The resultant blocks are merged together & inverse transformed to acquire the final fused image. Performance of the proposed work is evaluated with quantitative (visually) & qualitative analysis (Mutual Information, Quality factor) & compared with standard Brovey & SWT (stationary wavelet transform) methods.

Keywords: *Image Fusion; Hadamard Transform; Spatial Frequency, Entropy, visibility, standard deviation, correlation.*

1. INTRODUCTION

Image fusion is a process of fusion of multimodal medical images into a single image. This technique process leads to develop more advancement in the area of medical imaging. The resultant image will provide more information for further diagnosis [1]. The multi modal medical images are captured from various scanners like MRI, CT, and PET etc. Each scanner is having own specificity to display the details of body parts. Most of the times all scanners are giving information related to same body part of the same person but each report posses different information [2].

The fusion process carries either in spatial domain or transform domain. In spatial domain each pixel value of an image directly involves infusion processes. The techniques are Brovey, PCA (principal component analysis) etc. The problem arises using spatial domain techniques. This can be overcome with transform domain approaches. Here the transformed coefficients are fused instead of pixel values. The transform domain fusion techniques are DCT (Discrete cosine transform), DWT (Discrete wavelet transform), SWT (Stationary wavelet transform), Hadamard transform etc.

Image fusion methods are mainly divided in to three categories [3-6]: pixel level based image fusion, feature-level based image fusion and decision-making based image fusion. This paper concentrates on feature level image fusion.

Prakash,O.; Srivastava,R.; Khare,A.[7] proposed Biorthogonal wavelet transform based image fusion using absolute maximum fusion rule to improves fusion quality by reducing loss of significant information available in individual images. Thomas, E.; Nair, P.B.; John, S.N.; Dominic,M.[8] proposed Image fusion using Daubechies complex wavelet transform and lifting wavelet transform: A multiresolution approach is visually and quantitatively good. This method is tested against Gaussian, salt & papper and speckle noise. This technique is better than LWT method. . Mankar, R.; Daimiwal, N. [9] proposed Multimodal medical image fusion under Non subsampled contourlet transform(NSCT) domain provide more details about edges at curves and improve the resolution of the image for human perception.

Rest of the paper is organized as follows: image fusion and hadamard transform is discussed in Section II. The proposed fusion method is explained in section III. Experimental results and performance evaluations are given in Sections IV. Finally, conclusions of the work are given in Section V.

2. HADAMARD TRANSFORM

Hadamard transform is one of the non sinusoidal transmission technique in transform domain. This is a orthogonal transformation and it decomposes into a set of orthogonal, rectangular functions called Walsh functions [10].

The advantages of Hadamard transform include (*i*) its elements are real (*ii*) its rows and columns are orthogonal to each other [11]. Middle and high frequency bands of Hadamard transform are more useful compared to other high coding gain transforms like DCT and DWT at high noise environment. Due to this the vast application area of this transform is in image fusion. The kernel values of hadamard transform is either +1 or –1.

The basic hadamard transform is defined below:

$$H_{2\times 1} = \frac{1}{\sqrt{2\times 1}}\begin{bmatrix} H_1 & H_1 \\ H_1 & -H_1 \end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (1)$$

This is the lowest order Hadamard matrix with order 2 is H2. Hadamard matrices of any order N whose dimensions are power of two can be constructed using Eq. (2)

$$H_{2N} = \frac{1}{\sqrt{2}}\begin{bmatrix} H_N & H_N \\ H_N & -H_N \end{bmatrix} \quad (2)$$

Let [I] represents the original image with N × N size and [I'] is the transformed image. The 2D-Hadamard transform of [I] is given as:

$$[I'] = \frac{H_N[I]H_N}{N} \quad (3)$$

and its inverse is given by

$$[I] = \frac{H_N^{-1}[I']H_N^{*}}{N} = \frac{H_N[I']H_N^{*}}{N} \quad (4)$$

Where H_N represents N X N Hadamard matrix, whose dimensions are power of two. The orthoganility is defined as:

$$HH^T = 1 \quad (5)$$

3. PROPOSED WORK

In this paper, Hadamard transform is applied on input images. Before transformation consider the size of the input images must be same. The SPET image shows the brain function and has a low spatial resolution; the MRI image shows the brain tissue anatomy and contains no functional information. The proposed work flow is listed bellow and shown in Fig 1.

Step 1: Consider multi modal medical images MRI (I_1) and SPET (I_2). The RGB model PET image is represented in HIS color model to improve visual efficiency.

Step 2: The multimodal source images MRI and intensity component of SPET image are transformed into hadamard coefficients using equation 3.

Step 3: These coefficients are divided into 8*8 '*b*' ($I^1_l, i^2_l, \ldots I^b_l$) blocks. Each block features are compared with spatial frequency, entropy, visibility, correlation & standard deviation. The feature computation techniques are:

3.1. Spatial Frequency

The main use of the spatial frequency is to measure the clarity of image blocks and overall activity level in an image.

The spatial frequency is defined as

$$S_1 = \sqrt{(RF_1)^2 + (CF_1)^2} \tag{6}$$

Where $l = (1, 2)$

Where RF and CF are the row frequency

$$RF_1 = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}[I_1(m,n) - I_1(m,n-1)]^2} \tag{7}$$

and Column frequency

$$CF_l = \sqrt{\frac{1}{MN}\sum_{n=1}^{M}\sum_{n=2}^{N}[I_l(m,n) - I_l(m-1,n)]^2} \tag{8}$$

3.2. Entropy

The Entropy is calculated using the formula

$$H_l = \sum_{i=1}^{M}\sum_{j=1}^{N} p(I_1(i, j)) \log p(I_1(i, j)) \tag{9}$$

3.3. Correlation

It computes the correlation coefficient between input images I_1 and I_2 to computes the correlation coefficient using following equation:

$$c_l(I_1/I_2) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I_1(i,j) - \bar{I}_1\right)\left(I\ (i,j) - \bar{I}_2\right)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I_1(i,j) - \bar{I}_1\right)^2 \sum_{i=1}^{M}\sum_{j=1}^{N}\left(I_2(i,j) - \bar{I}_2\right)^2}} \tag{10}$$

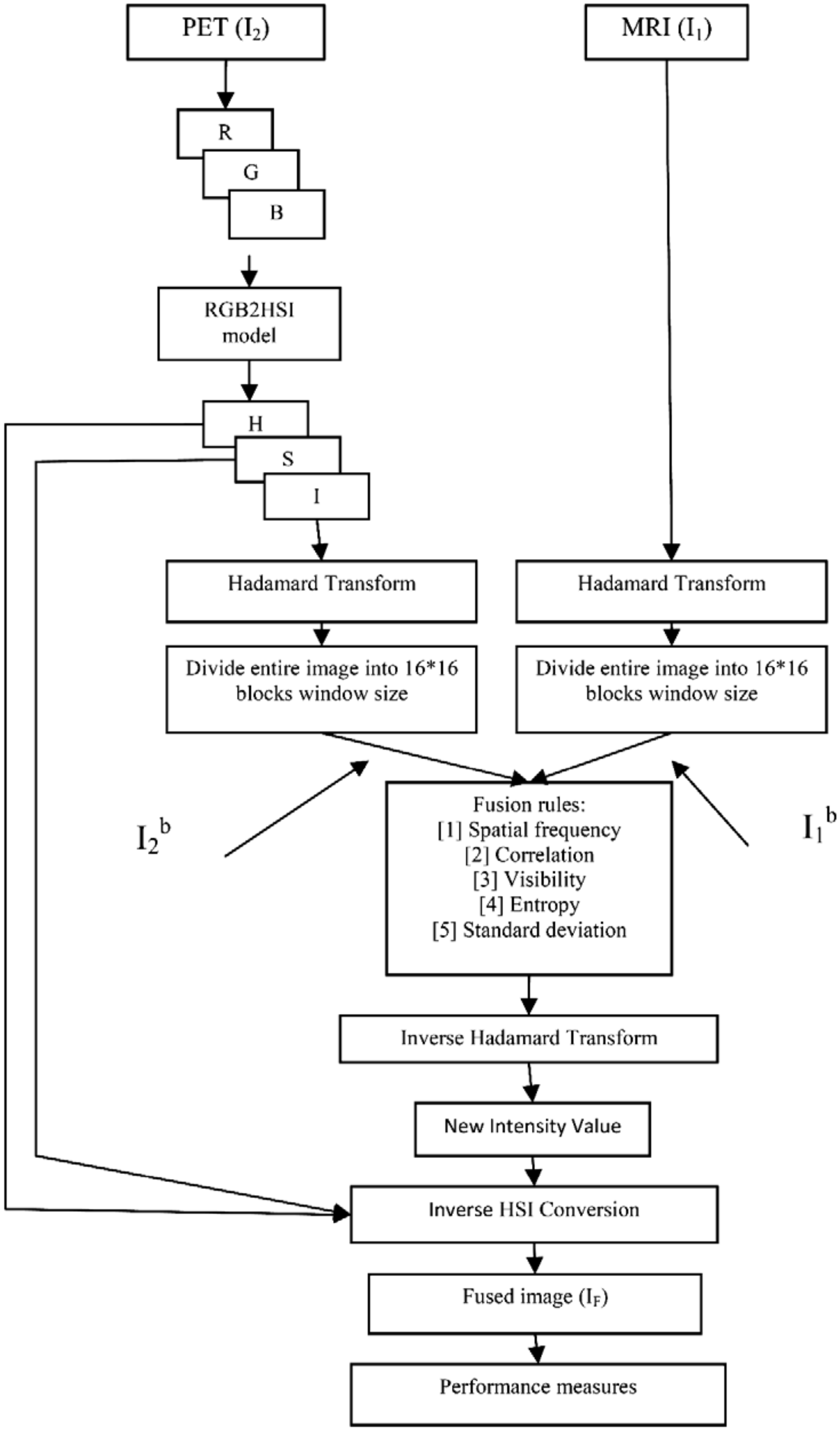


Figure 1: A Schematic diagram of proposed Hadamard Transform based image fusion method

3.4. Visibility

$$v_l = \sum_{m=1}^{M}\sum_{n=1}^{N}\left|\frac{I_l(m,n)-\mu_{I_l}}{\mu_{I_l}^{\alpha+1}}\right| \quad (11)$$

Where μ_{I_l} average intensity value of image block and α is is a constant.

3.5. Standard Deviation

Standard deviation is the square root of variance, which reflects the spread in data and is given by:

$$St_l = \sqrt{\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(I_l(i,j)-\bar{I}_l\right)^2}{mn}} \quad (12)$$

Step 4: The above features are compared with fusion process & resultant block is placed in fused image.

3.6. Fusion rule

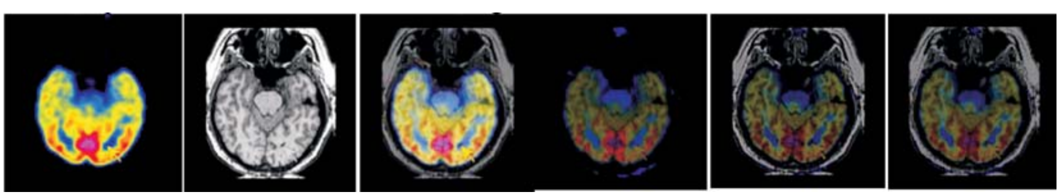
$$fus^P = \begin{cases} I_1(x,y) & s_1 > s_2 \;\&\; v_1 > v_2 \;\&\; c_1 > c_2 \;\&\; H_1 > H_2 \;\&\; st_1 > st_2 \\ I_2(x,y) & s_1 < s_2 \;\&\; v_1 < v_2 \;\&\; c_1 < c_2 \;\&\; H_1 < H_2 \;\&\; st_1 < st_2 \\ (I_1(x,y)+I_2(x,y))/2 & \text{otherwise} \end{cases}$$

Where P is number of blocks from 1,2,…….*b*.

Step 5: Apply inverse Hadamard transform for the fused coefficients (fus^P) to acquire final fused image (I_F).

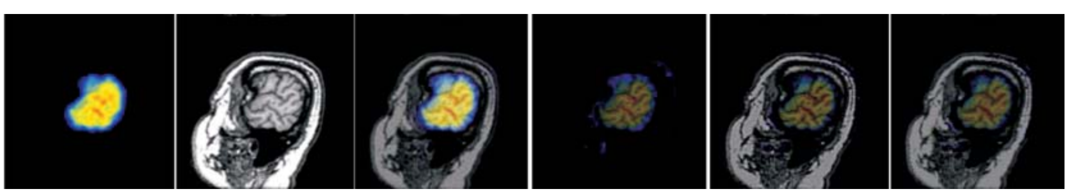
4. EXPERIMENTAL RESULTS

This section analysis visual and quantitative strength of the proposed method. Experiments have been performed over SPET -MRI images.



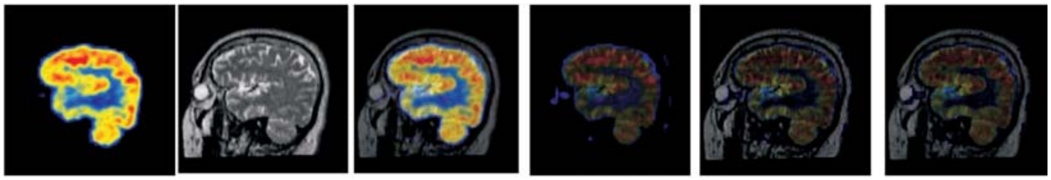
(*a*) (*b*) (*c*) (*d*) (*e*) (*f*)

Figure 2: A New: Mild Alzheimer's disease MRI & SPET images 1 (*a*) and (*b*) respectively, (*c*) ground truth image, (*d*) fused with Brovey method, (*e*) fused with SWT, (*f*) the proposed method



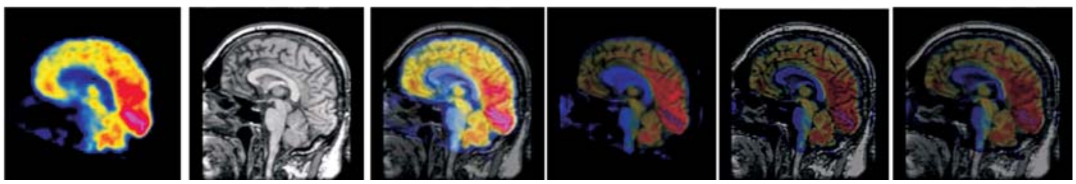
(*a*) (*b*) (*c*) (*d*) (*e*) (*f*)

Figure 3: New: Mild Alzheimer's disease MRI & SPET images 2 (*a*) and (*b*) respectively, (*c*) ground truth image, (*d*) fused with Brovey method, (*e*) fused with SWT, (*f*) the proposed method



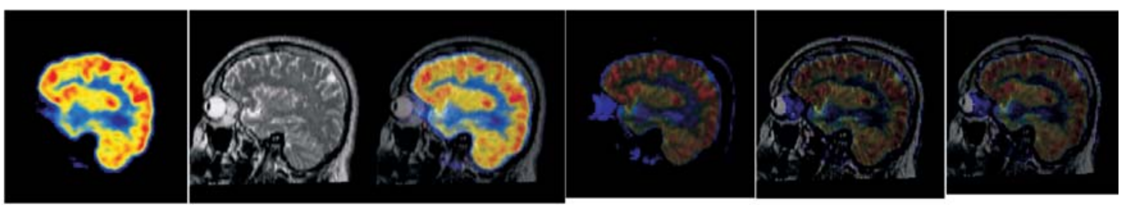
(*a*) (*b*) (*c*) (*d*) (*e*) (*f*)

Figure 4: New: Mild Alzheimer's disease MRI & SPET images 3 (*a*) and (*b*) respectively, (*c*) ground truth image, (*d*) fused with Brovey method, (*e*) fused with SWT, (*f*) the proposed method



(*a*) (*b*) (*c*) (*d*) (*e*) (*f*)

Figure 5: New: Mild Alzheimer's disease MRI & SPET images 4 (*a*) and (*b*) respectively, (*c*) ground truth image, (*d*) fused with Brovey method, (*e*) fused with SWT, (*f*) the proposed method



(*a*) (*b*) (*c*) (*d*) (*e*) (*f*)

Figure 6: New: Mild Alzheimer's disease MRI & SPET images 5 (*a*) and (*b*) respectively, (*c*) ground truth image, (*d*) fused with Brovey method, (*e*) fused with SWT, (*f*) the proposed method

The above shown results are proves the visual clarity of the proposed method. The quantitative analysis can be proved with the various quality metrics.

The following fig from fig (2-6) will give visual comparison of proposed method with standard Brovey & SWT fusion technique.

Graphical representation of performance evaluation parameters are shown below (Fig 7). For evaluation of the proposed method with mutual information and quality factors.

4.1. Mutual Information

Mutual information of two random variables is a quantity that measures the mutual dependence of the two variables. Here, MI measures the information that reference and the fused image share:

$$\mathrm{MI}_{\mathrm{RI_F}} = \sum_{i=1}^{\mathrm{L}}\sum_{j=1}^{\mathrm{L}} \mathrm{P}_{\mathrm{RI_F}}(i, j)\log_2 \frac{\mathrm{P}_{\mathrm{RI_F}}(i, j)}{\mathrm{P_R}(i)\mathrm{P}_{\mathrm{I_F}}(j)} \tag{14}$$

Where $\mathrm{P}_{\mathrm{RI_F}}$ is the normalized joint gray level histogram of images R and $\mathrm{I_F}$, $\mathrm{P_R}$ and $\mathrm{P_I}$F are the normalized marginal histograms of the two images [12].

Quality factor ($\mathrm{Q}^{\mathrm{I_1I_2/I_F}}$)

$$Q^{I_1 I_2 / I_F} = \frac{\sum_{n=1}^{N}\sum_{m=1}^{M}\left(Q^{I_1 I_F}(n,m)\,W^{I_1}(n,m) + Q^{I_2 I_F}(n,m)\,W^{I_2}(n,m)\right)}{\sum_{n=1}^{N}\sum_{m=1}^{M}\left(W^{I_1}(n,m) + W^{I_2}(n,m)\right)} \qquad (15)$$

Where $Q^{I_1 I_F}(n, m) = Q_g^{I_1 I_F}(n, m)\, Q_\alpha^{I_1 I_F}(n, m)$; $Q_g^{I_1 I_F}(n, m)$ and $Q_\alpha^{I_1 I_F}(n, m)$ are the edge strength and orientation preservation values, respectively; ^{n,m} represents the image location; and N, M are the size of images, respectively. $Q^{I_2 I_F}(n, m)$ is similar to $Q^{I_1 I_F}(n, m)$. W^{I_1} and $W^{I_2}(n, m)$ reflect the importance of $Q^{I_1 I_F}(n, m)$ and $Q^{I_2 I_F}(n, m)$, respectively [13-14].

Table 1
Comparison of performance measures

Fused images	*Fusion methods*	*Fusion Metrics*	
		MI	$Q^{AB/F}$
MRI & SPET Image 1	Brovey method	0.7605	0.0630
	SWT	1.5638	0.0006
	Proposed method	2.9404	0.0003
MRI & SPET Image 2	Brovey method	0.1090	0.0247
	SWT	1.7097	0.0005
	Proposed method	3.0187	0.0003
MRI & SPET Image 3	Brovey method	0.9674	0.0588
	SWT	1.5066	0.0003
	Proposed method	2.9859	0.0002
MRI & SPET Image 4	Brovey method	1.4947	0.0524
	SWT	3.5423	0.0004
	Proposed method	3.6168	0.0002
MRI & SPET Image 5	Brovey method	1.0812	0.0551
	SWT	1.4847	0.0004
	Proposed method	2.9948	0.0002

For Table 1 refer graphical representation of performance evaluation parameters are shown below (Fig 7):

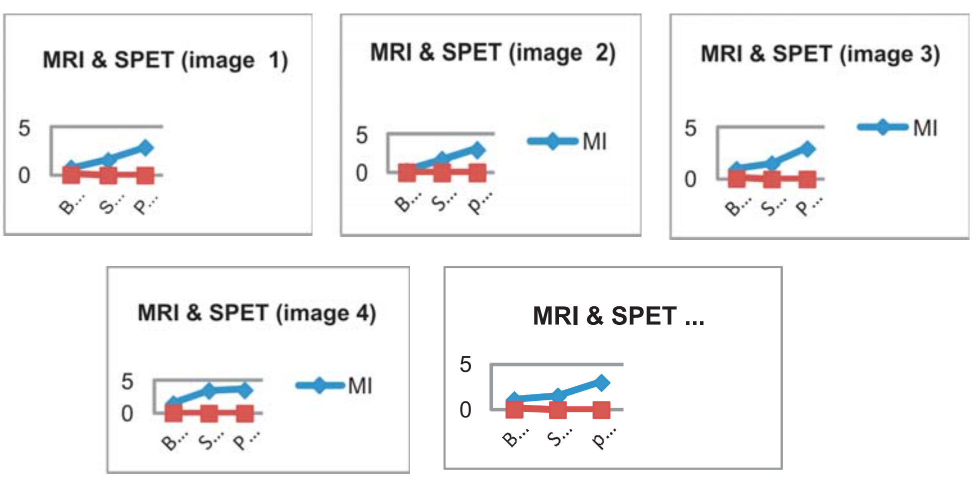


Figure 7: Graphical Representation of various performance measures. (*a*) Mutual information (*b*) Quality factor ($Q^{AB/F}$)

5. CONCLUSION

The fusion of image plays a vital role in diagnostics. In this work, a novel hadamard transform based fusion process is proposed. The hadamard transform based fusion is new era of technique in transform domain. The features of hadamard coefficients are computed with various techniques. The values show the strength of the information in the image. These values are used for fusion decision making. The best values of MI & Quality factor tells about the strength of the proposed method. The performance measures proved that the proposed method is efficient than the standard transform domain methods. The resultant image is having quality both visually and quantitatively. This may be extended with various fusion rules to acquire more effective fusion image.

6. ACKNOWLEDGMENT

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