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Comparison of Different Image Fusion Techniques for 2D MRI Images

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***Abstract*—**Image fusion is the process of combining relevant information from two or more images into a single image. The resulting image contains more information than the input images. Thus data fusion combines partial and varied information which is present in multiple images and forms a single image having the collective features of all the input images. It has two main aims which are removal of partial redundant data, as all sources provide information about the same phenomenon ;and Other is the complementarities between data as each source provides a different view about the same phenomenon. Two techniques are implemented for image fusion which are Wavelet Transform and Fuzzy Logic. The results of these techniques are compared based on Entropy, Standard Deviation and Mutual Information.

Keywords *-Fuzzy Inference System (FIS); Membership functions(mf); Entropy (EN); Standard Deviation(SD); Mutual Information (MI)*

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I. INTRODUCTION

The fusion techniques find many applications in real life. As single fused image is stored instead of multiple images the storage space required is reduced. Fast image retrieval is possible, since knowledge base has less number of stored images (fused). It also reduces the possibility of data replication, i.e .the patient data stored is reduced. Image fusion technique has become a common application used within medical diagnostics and treatment. Fused images may be created from multiple images which are obtained from the same imaging modality or by combining information from multiple modalities, such as magnetic resonance image (MRI), computed tomography (CT), positron emission tomography (PET), and single photon emission computed tomography (SPECT)[8]. In radiology and radiation oncology, these images are used for different purposes[10]. For example, CT images provide more information related to bony structure while MRI images are typically give more information about the tissues hence used to diagnose brain tumors.

Thus image Fusion improves the quality of information from a set of images. Important applications of the fusion of images is in the area of medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. Quality of this fused image we can judge in terms of performance parameter like Entropy (EN), Standard Deviation (SD), and Mutual Information (MI). Recently, Discrete Wavelet Transform (DWT) and Fuzzy Logic Based Image Fusion techniques have been popular fusion of images. These methods give much better result than simple averaging, maximum, minimum.

This paper is organized into five sections. In section 1 Different Image Fusion techniques are mentioned. In section 2 Image fusion with wavelet transform using average and maximum coefficient method is explained. In section 3 Image fusion technique using Fuzzy Logic is explained. Section 4 consists of comparison of these fusion techniques. Section 5 comprises of conclusion and Results.

II. IMAGE FUSION TECHNIQUES

Image fusion has important applications in many different image processing fields such as satellite imaging, remote sensing and medical imaging. Image fusion method can be broadly classified into two groups[5] – A. Spatial domain fusion method B. Transform domain fusion

A. Spatial Domain

Spatial domain methods does direct processing on the pixels of an input image. A mathematical expression for spatial domain processing is given by the equation1

$$g(x ,y) = T[f(x ,y)] \quad .....(1)$$

Here ,the original image is given by f(x, y),and processed image by g(x, y) and T is an operator which is applied over neighbourhood of (x, y). The neighbourhood is defined about a point (x, y) and it is of a square or rectangular type with sub image area centred at (x, y). Spatial domain filtering can be applied for smoothing and sharpening purposes.

Here Fuzzy Logic based method is implemented which combines the pixel intensities of the source images depending on the Fuzzy rule selected. This fusion method gives the better result with preservation of data from input or source images.

B. Frequency Domain

Drawback of Spatial distortion can be minimized by frequency domain[9] method of image fusion. The multi resolution analysis is a useful tool for analysis of remote sensing images. The discrete wavelet transform is useful technique for fusion.

The steps in wavelet fusion method involves decomposition of images and detail components of decomposition are combined at different levels this results in the new detail components in the different bands of the image which causes merging or fusion of 3 images. The inverse discrete wavelet transform is implemented to reconstruct the fused image. The fused image preserves details and edge of the input or source images.

III. IMAGE FUSION USING WAVELET TRANSFORM

DWT[1] using Harr Transform for the three input MRI images is computed. This computes approximation coefficient matrix A ,Details coefficient matrices Horizontal H, Vertical V and Diagonal D. Hence for the three I/P Images there will be three matrices of each type. To find the matrices of the resultant fused image these I/P coefficients can be averaged or maximum out of them is computed. Hence there are two methods Average and Maximum Coefficient. Then from these resultant coefficient values inverse DWT is computed This forms the Fused resultant Image[7]. Fig.1 shows the Block Diagram of Wavelet Based Image fusion technique

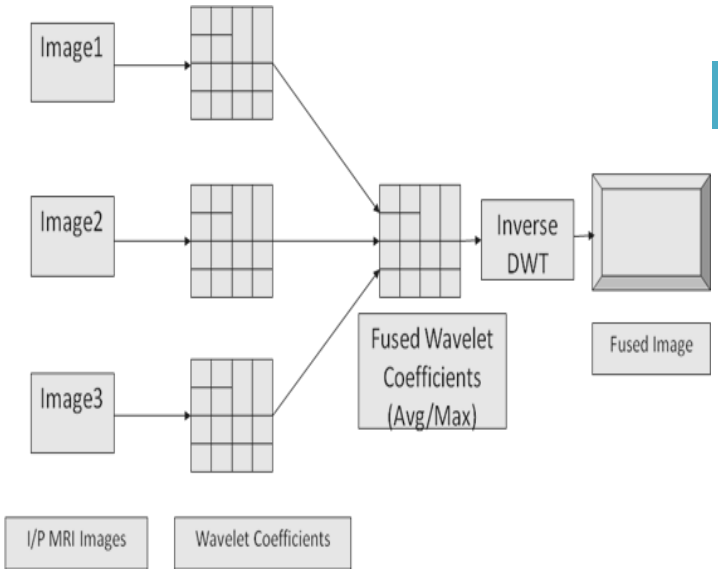

Figure1:Block Diagram of Wavelet Based Image fusion

A. *Simple Average*

When DWT using Harrr transform is applied to three Input images the coefficient matrices A,H,V,D are obtained for all three images. The corresponding matrices of input images are added and divided by three to compute the average value. Equation 2 shows the mathematical expression used for calculating average of A matrix. Similarly H,V and D average coefficient matrices are computed.

$$A_{FI} = (A_1 + A_2 + A_3) / 3 \quad .....(2)$$

Inverse DWT is computed from these matrices which forms the resultant fused image.

The main drawback of taking average value is that intensity levels will be average out hence contrast information will be reduced.

B. *Select Maximum*

The greater the pixel values the image is more focused. Thus this algorithm selects the in-focus regions from the input images by selecting the greatest value for each pixel, which results in output which is highly focused output. The value of coefficient matrices of input images are compared to each other. The greatest value matrix is assigned for the fused image as mentioned in equation 3. Similarly maximum value of H,V,D matrices of the fused image are computed.

$$A_{FI} = \max (A_1 , A_2 , A_3) \quad .....(3)$$

Due to maximum value image contrast is improved.

IV. IMAGE FUSION USING FUZZY LOGIC

Image fusion can be done with different methods, here image fusion using fuzzy logic[2] is implemented .Figure 2 shows the block diagram of Fuzzy based fusion technique. Three input images are fused together using mamdani's fusion rules. Total there are five membership functions defined. So in the total gray level span of 0-255 is divided into five parts i.e; membership functions.

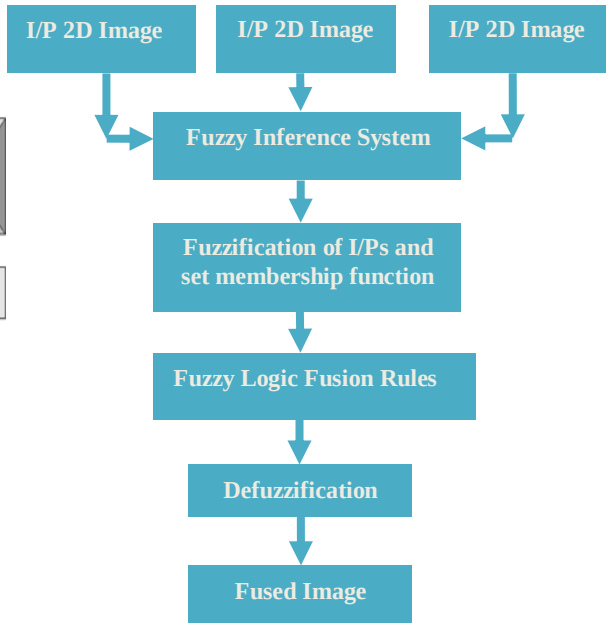

Figure 2 : Block Diagram of Fuzzy Based Image fusion

For the fuzzy system, the fusion rules are defined in the form of "IF-THEN" statement. These rules are designed in the form of combination of different input images which is as defined in the equation (4)

$$\beta(t) = \max\{ P_1 , P_2 , P_3\} = \{(S, M, L) \rightarrow L\} \quad .....(4)$$

where P_1 ,P_2 and P_3 indicate pixel gray level values of MRI images. Equation (4) shows that if P_1 is small gray level, P_2 is medium gray level and P_3 is Large gray level then output is large gray level. Likewise there are 25 possible combinations

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are defined. Figure 3 indicates diagram of Fuzzy Inference System. Three input images i.e; im1 ,im2, im3 are fused based on the mamdani's fusion rules and gives resultant fused image.

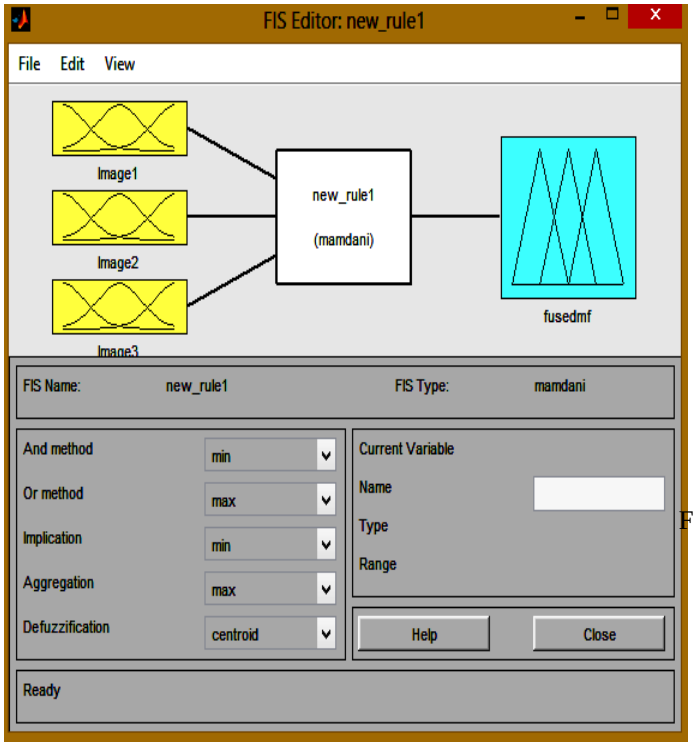

Figure3: Diagram of Fuzzy Inference System

V. PERFORMANCE MEASURES

The results of the fusion techniques used i.e; wavelet based and Fuzzy Logic based are as shown in figure 4. But these image fusion techniques can be compared[4,6] based on the following terms: Entropy, Standard Deviation, Mutual Information.

A. Entropy (EN)

Entropy value gives measure of information content in the image. A higher value of Entropy displays better fusion results. The entropy[3] of an image is calculated using the formula mentioned in equation 5 as follows:

$$EN = -\sum_{i=0}^{L-1} Pi \, Log_2 Pi \qquad .....(5)$$

Where L is the maximum intensity value for a pixel in the image (in this case 255) and pi is the normalized histogram frequency of the fused image.

B. Standard deviation (SD)

The standard deviation (SD) calculates the amount of variation or dispersion from the average value. A low standard deviation indicates that the data points are very close to the average value (also called expected value); a high standard deviation indicates that the data points are separated out over a large range of values. SD also indicates the strength of signal . Higher value of SD indicates that image has high contrast. The formula to calculate SD is as shown in equation 6 :

$$\sigma = [(\sum X_{(j,k)} - m)^2/MN]^{1/2}) \qquad .....(6)$$

where the size of image is M X N, $X_{(j,k)}$ represents the intensity value of the $(j,k)^{th}$ pixel and m is the mean of all intensity values of the image.

C. Mutual Information (MI)

Mutual information of three registered images I_1,I_2 and I_3 is given by

$$M(I_1,I_2,I_3) = EN(I_1)+ EN(I_2)+ EN(I_3) - EN(I_1,I_2,I_3) .....(7)$$

where EN represents the entropy of the corresponding images and $EN(I_1,I_2,I_3)$ represents the joint entropy of the three images. A higher value of $M(I_1,I_2,I_3)$ represents better fusion of the two images.

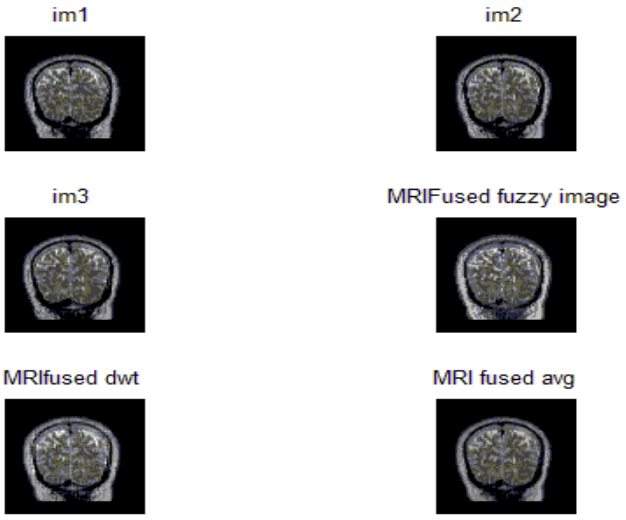

Figure 4: Result of Image Fusion Techniques

TABLEI COMPARISON OF PERFORMANCE PARAMETERS BETWEEN DIFFERENT FUSION METHODS

Fusion Method	Entropy	Standard Deviation	Mutual Information
Wavelet Transform Average coefficient	1.0141	35.8576	9.7914
Wavelet Transform Maximum Coefficient	0.9951	41.0003	9.8105
Fuzzy Logic Based Fusion	3.6567	36.2012	10.8055

TABLE II COMPARISON BETWEEN DIFFERENT FUSION METHODS

Fusion Method	Advantages	Disadvantages
Wavelet Transform Average coefficient	When images are merged in wavelet package space different frequency ranges are processed differently.	The drawback of Pyramid Transform and DWT is that they suffered from shift variance .
Wavelet Transform Max coefficient	Better Image contrast	As Entropy is minimum details of information content is less.
Fuzzy Logic Based Fusion	Also, Fuzzy logic based method provides the better retention of information from both the source images in the fused image as verified by the higher values of Mutual Information.	Low image contrast as compared to Wavelet transform max coefficient Method.

VI. SIMULATION RESULTS & DISCUSSION

As higher value of Entropy gives better fusion result as Entropy for Fuzzy based method is highest it gives better fusion result. Higher value of standard deviation indicates high contrast and as wavelet based maximum coefficient method gives highest SD it will provide high contrast as compared to other methods. Also, Fuzzy logic based method provides the better retention of information from both the source images in the fused image as verified by the higher values of Mutual Information. The above information is verified from the Table I which compares fusion techniques based on parameters. Table II compares advantages and drawbacks of the fusion techniques discussed. and same justified with the visualization of the fused image also.

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