Fuzzy Based Multimodal Medical Image Fusion

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***Abstract*—Medical image fusion is a field which merge medical science and technology. Recently image fusion techniques have found lot of application in the clinical treatment and diagnosis, surgical treatment of brain and diagnosis of tumor etc. Several methods of medical image fusions are available presently. But most of the methods suffer from the noise and artefacts because of higher contrast. The main problem with medical image fusion is to say a certain criteria must be better than another in a variety of image fusion optimization criteria, as there is absence of perfect reference image to be compared. This paper deals with an image fusion technique to combine both CT scan and MRI scan image of brain. The project starts with basic concept of image fusion and have gone through different existing fusion technique. And also have come to a conclusion that fuzzy logic can be best suited for CT and MRI image fusion as we need to incorporate complimentary information from both the images. Here the two real medical images are registered and a fusion using fuzzy logic is proposed. The quality of the fused image is measured using mutual information and structural similarity index and visual perception. The proposed method gives better results in terms of image quality metrics compared to many of the existing methods.**

Keywords*— *Discrete wavelet transform, Dual Tree-Complex Wavelet Transform, Principal Component Analysis, Mutual Information, Stationary Wavelet Transform, Structural Similarity Index.

I. INTRODUCTION

Nowadays with increasing progress in technology, medical image fusion draws attentions as there is an increasing demand in clinical area like surgery , radiotherapy etc. Multimodality imaging is the use of two or more imaging techniques (modalities) to provide information in a given diagnostic or research situation. The goal of multimodality medical image fusion is to merge information from multiple images of the different modality of the same scene into a single image, conserving the required features from each of the original images, providing a better result which is good for visual perception. The fused image will better the image analysis used for medical purposes. It is one of the most faithful techniques for detecting many diseases like tumors and fractures and also for delineation of lesions for radio therapy.

Medical image fusion can be used to improve diagnostic accuracy by correctly positioning intracranial lesions and also for brain imaging. Some medical image fusion technique can be used to monitor tumor changes before surgery and for radiation treatment. For surgery, it is possible to clearly understand how the lesions is surrounded by the tissue, whichleads to success of the operation. The same can be used to determine the accumulation of anatomy (CT) withaccumulation of radiolabeled monoclonal antibody (SPECT) for the correct classification and positioning of tumor before treatment etc.

From the literature review it can be clearly realized that fuzzy logic plays important role in image fusion process [1]-[4]. Fuzzy logic deals with degrees of truthness in place of the usual true or false (1 or 0) on which the modern computer is based. Fuzzy logic works exactly the way our brains works. So fuzzy logic is best suited for solving the uncertainty in image fusion. This paper explains such an image fusion method using proper fuzzy rules and quality of image fusion is compare with some of the existing fusion method in terms of image quality metrices.

II. PROBLEM DEFINITION

In situations where physicians need more details to deal with medical diagnosis and treatment medical image fusion is needed. Recently various many researches have been carried out on medical image fusion and can be seen in literature review [4]-[6]. But many of these methods suffer from the noise and other artefacts as they tend to have higher contrast. Main difficulty to identify a particular image quality assessment parameter to predict which fusion method is better as there is no reference image [7]. There are many papers to available on the literature review and many fusion approaches have been proposed. Different papers deal the problem using different image quality metric like peak signal to noise ratio (PSNR), structural similarity index (SSIM), standard deviation, entropy etc. Fuzzy logic has been identified as the useful method for medical image fusion. Many journal papers are available on fuzzy logic with different transformation andfusion rules applied. So it is a necessity to find proper fusion method and rules for medical image fusion that take into account the quality of fused image.

III.EXPERIMENT AND BACKGROUND THEORY

A. Image Registration

Real CT and MRI images are used as input which is registered using automatic intensity based registration. This include specifying the input images and a metric and optimizer and transformation type .In the input images specified one will be taken as fixed image and the other as moving image. It start with the transformation type we specified and an internally determined transformation matrix. An image transformation will be determined to be applied to the moving image with bilinear interpolation. Then the metric measures similarity between the fixed image and transformed moving image and returns a scalar value. Using this value the optimizer check for stop condition and if stop

condition is not reached, it adjusts the transformation matrix to start the next iteration

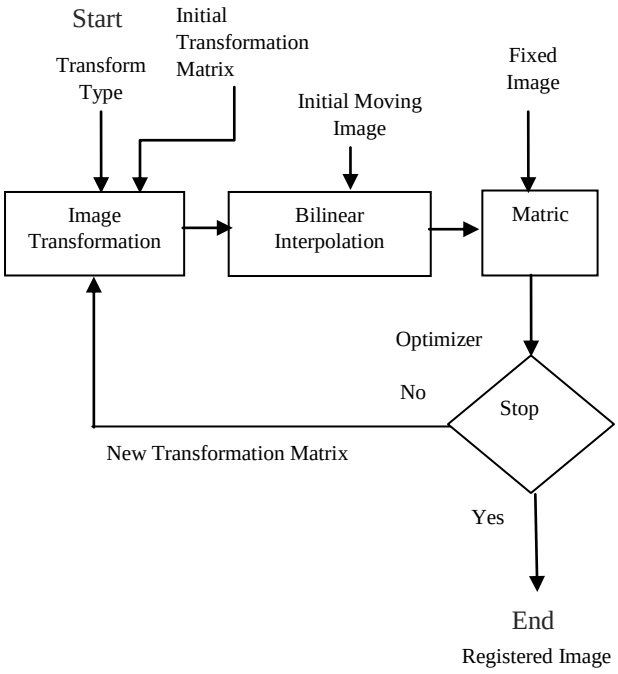

Fig.1 Image registration process

B. Discrete Wavelet Transform (DWT)

DWT is used for multi-resolution representation of signals based on wavelet decomposition. Wavelets allow analysis of both time and frequency characteristics of signals simultaneously because of the fact that the energy of wavelets is concentrated in time and still possesses the wave-like periodic characteristics. This transform decomposes the signal into mutually orthogonal set of wavelets. It is used to transform image pixels into wavelets in image processing.The DWT is defined as

$$W\varphi(j_0,k)=\frac{1}{\sqrt{\mathrm{M}}}\sum_{x}f(x)\varphi_{j0,k}(x)(1)$$

$$W\psi(j,k)=\frac{1}{\sqrt{\mathrm{M}}}\sum_{k}f(x)\psi_{j,k}(x) \qquad (2)$$

For $j\geq j_0$, where $f(x),\varphi_{j_0,k}(x)$, and $\psi_{j,k}(x)$ arefunctionsof the discrete variable x =0,1,2,…,M−1.

C. Stationary Wavelet Transform (SWT)

SWT is another form of DWT. It overcomes the variant nature of DWT. Or in another words, it is the decimated version of DWT. It modifies the filters at each level by padding zeroes. So computationally it is complex.

D. Dual Tree Complex Wavelet Transform (DT-CWT)

The dual tree-complex wavelet transform (DT-CWT) is also an enhancement to the discrete wavelet transform (DWT), with important additional properties. It generates complex coefficients by using a dual tree of wavelet filters to obtain their real and imaginary parts or calculates the complex transform of a signal using two separate DWT decompositions. It is directionally selective in two and higher dimensions and also shift invariant in nature.

E. Wavelet Packet Transform (WPT)

It is also known as Optimal Sub band Tree Structuring (SB-TS) and is a wavelet transform where the discrete-time or sampled signal is passed through more filters than DWT. In DWT, at each level approximation coefficient is passed through discrete time low and high pass quadrature mirror filter. But in wavelet packet decomposition both the detail and approximation coefficients are decomposed to create the full binary tree.

F. Fusion by Wavelet Transformation and Averaging

Here the input images are registered and transformation using DWT, SWT, and DT-CWT is done and fusion is performed based on averaging rules and structural similarity index and mutual information is calculated and tabulated.

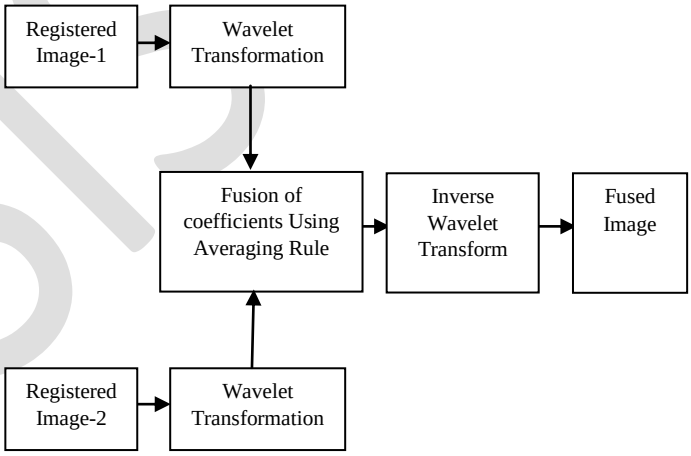

Fig.2 Fusion using Wavelet transformation and averaging rule

G. Principal Component Analysis (PCA) Based Image Fusion

It is a statistical procedure that converts a set of observation of correlated variables into set of values linearly uncorrelated variables called principal component through an orthogonal transform. Number of principal components are always less than or equal to the original variables.

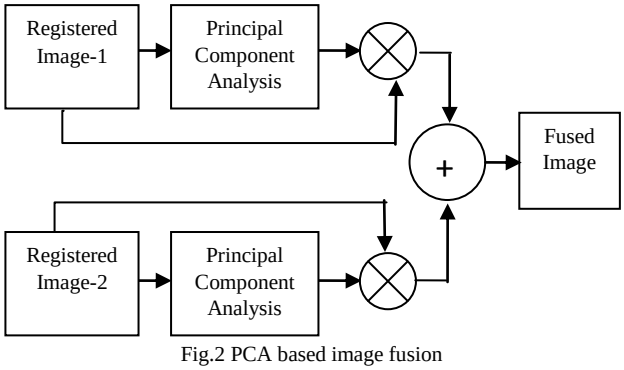

Fig.2 PCA based image fusion

H. Fuzzy Logic

Fuzzy is an extension of multivalued logic or in another sense extension of set theory which deals with classes of objects in which membership is a matter of degree. Basic idea behind fuzzy logic is that it uses linguistic variable whose values are words rather than numbers. Although words are less precise than numbers, they work almost like a human brain. Fuzzy logic system make use of membership functions and fuzzy if- then rules to take required decision for solving the problem where it is applied. In image processing it is common to deal with subjective concepts like edges, brightness etc. That is the reason why fuzzy logic is incorporated with image processing.

I. Image Fusion Using Fuzzy Logic

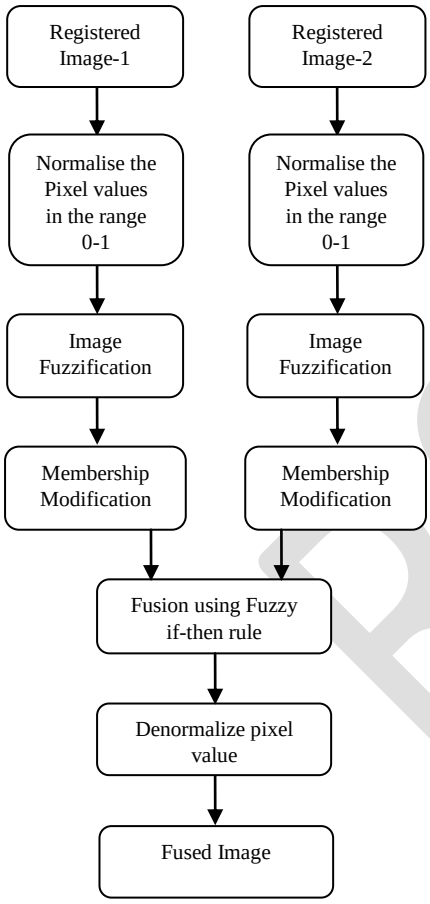

Fig.3 Fuzzy based image fusion

Block diagram for image fusion using fuzzy logic is as shown above. Image fusion by applying wavelet transform such as DWT, SWT, DT-CWT and WPT to images and then by using fuzzy logicis done .All the maximum possible membership function and rules are tried to get better result in terms of SSIM and MI and visual perception. And also fusion using fuzzy logic in spatial domain is tried.

IV. PERFORMANCEANALYSIS

A. Structural Similarity Index (SSIM)

The structural similarity (SSIM) index measures the similarity between two images based on eye perception. It is designed to improve on traditional methods like peak signal to noise ratio (PSNR) and mean square error (MSE), which does not take into account the perceived error. Structural similarity between two images x and y of size N*N is given below

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c1)(2\sigma_{xy} + c2)}{(\mu^2{}_x + \mu^2{}_y + c1)(\sigma^2{}_x + \sigma^2{}_y + c2)} \quad (3)$$

B. Mutual information (MI)

Mutual information between two images x and y is given byMI (x,y) = H(x) + H(y) – H(x,y) (4)
Where H(x) and H(y) are entropy of images x and y and H(x,y) is the joint entropy of two images

V. RESULTS

Fusion Method	SSIM	MI
DWT-Averaging	0.77	3.9
SWT-Averaging	0.83	4.2
PCA Based Fusion	0.69	4.2
DT-CWT-Averaging	0.78	3.7
WPT-Fussy Based	0.50	3.9
SWT-Fuzzy Based	0.66	4.3
DWT-Fuzzy Based	0.50	3.9
DT-CWT-Fuzzy Based	0.61	4.2
Proposed Method-Spatial Domain Fuzzy Logic Based	0.72	5.96

Table 1. Fusion Quality Comparison

A. Result of Image Registration

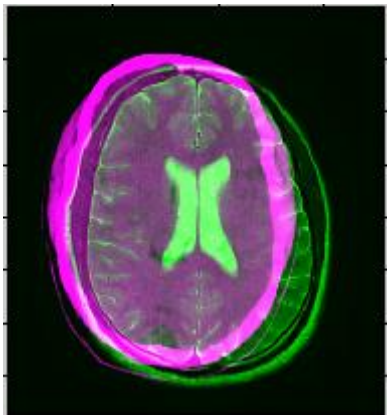

Fig. 4a CT and MRI Images before Registration

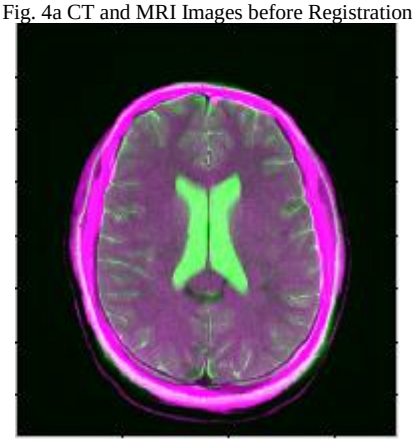

Fig. 4b CT and MRI Images after Registration

B. Result of Image Fusion

Fig. 5a Input Image1(CT)

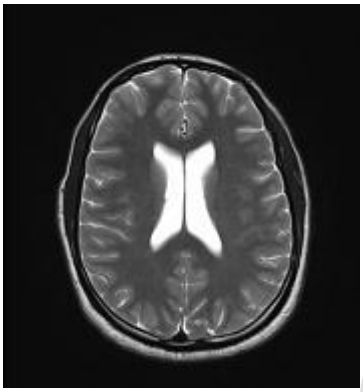

Fig. 5b Input Image2(MRI)

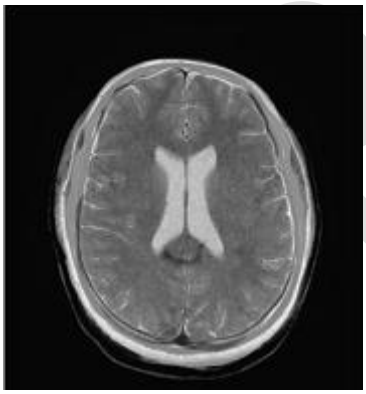

Fig. 5c Fused Image using DWT and averaging Rule

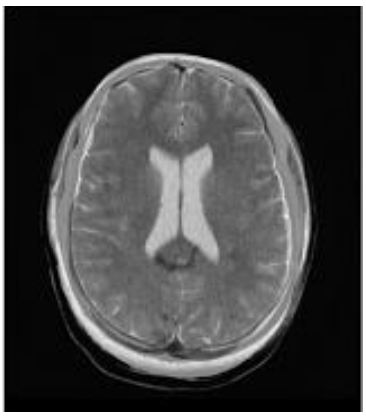

Fig. 5d Fused Image using SWT and averaging Rule

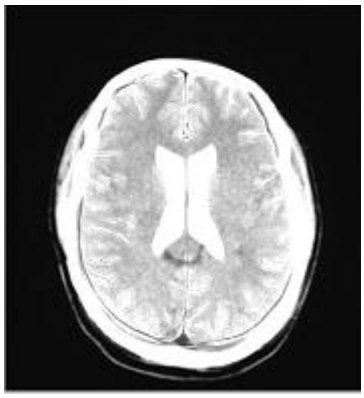

Fig. 5e Fused Image using DT-CWT and averaging Rule

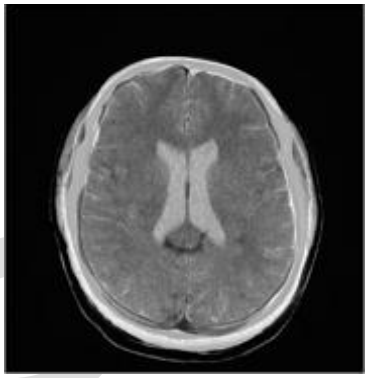

Fig. 5f PCA Based Fused Image

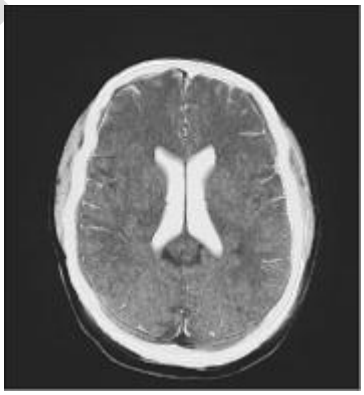

Fig. 5g Fused Image using DWT and Fuzzy Logic

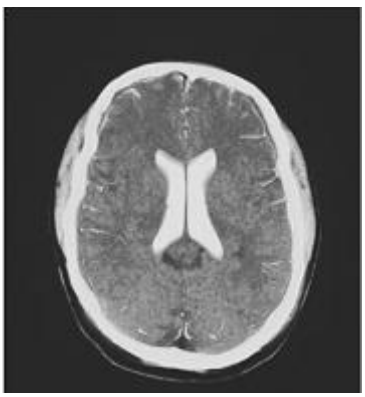

Fig. 5h Fused Image using SWT and Fuzzy Logic

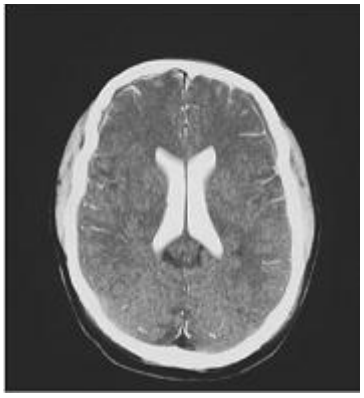

Fig. 5i Fused Image using DT-CWT and Fuzzy Logic

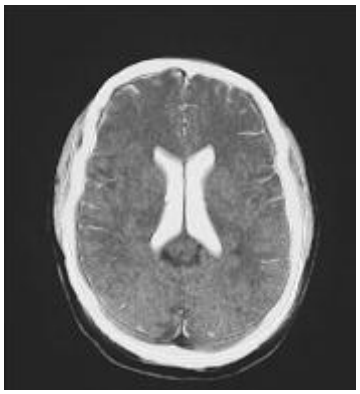

Fig. 5j Fused Image using WPT and Fuzzy Logic

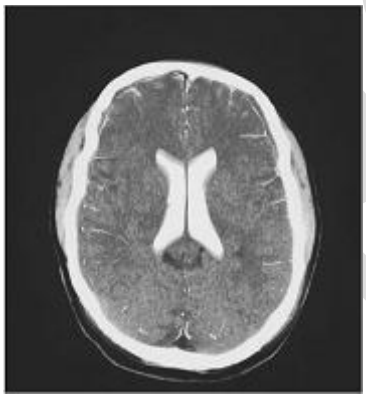

Fig. 5k Fused Image using Fuzzy Logic in Spatial Domain

VI. CONCLUSIONS

Fusion of real CT and MRI brain image is carried out using wavelet transform such as DWT, SWT, DT-CWT and averaging rule. Also fusion by incorporating wavelet transform and fuzzy logic is performed.Almost all possible combination of membership function and rules are tried with these. But fusion using fuzzy logic without any transformation, that is in spatial domain gives better result in terms of structural similarity index, mutual information and visual perception

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