Comparative Analysis of Medical Image Fusion Techniques Using Lifting Wavelet Transform

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Abstract: Image fusion is the process of combining information from multiple input sources. The goal of image fusion is to enhance the quality of information from a set of input images. In this paper, Lifting Wavelet Transform (LWT) based three different medical image fusion techniques has been implemented and analyzed. CT and MRI images were decomposed using LWT separately. The fusion between two transformed images was based on coefficient fusion rule which included the choice of averaging, Average-Variance (AV) and Improved Average-Variance (IAV) method. Fused wavelet coefficients are reconstructed using inverse LWT to obtain fused image .Multiple experiments were conducted by using three fusion techniques and comparative analysis has been performed with some metrics such as information entropy, mutual information, correlation coefficient, peak signal to noise ratio, standard deviation and signal to noise ratio. Simulation results show that the IAV technique is more suitable for medical image fusion than other techniques in wavelet domain.

Keywords: *Average- Variance, Correlation Coefficient, Improved Average- Variance, Lifting Wavelet Transform, Medical Image Fusion and Standard Deviation.*

I. INTRODUCTION

Medical imaging system plays a vital role in human health care and it provides complete information about human body for better treatment. For example, Magnetic Resonance Imaging (MRI) provides clear information about soft tissue and Computed Tomography (CT) gives bone structures [1]. Fusion is mechanism in which two or more input images are united to obtain new image as a fused image. Fused image have more accurate and relevant information than the input images. Medical image fusion is significant in medical field to combine two or more human body images into one [2]. It is very useful to identify diseases in human body and possible diagnosis so that good treatment applied. The objective of medical image fusion is to maximize the information and improve the quality of the image by collecting strongest features provided by different modalities.

Image fusion can be categorized into three: Pixel level fusion, Feature level fusion and Decision level fusion. Pixel level fusion [3] related with the information associated with input image pixel and fused image can be obtained from the corresponding pixel values of input images. Input images are segmented into small regions and features are used for fusion in feature level fusion [4]. Decision level fusion [5] is based on statistics, fuzzy logic prediction and heuristic. For the proposed work, the system considered pixel level image fusion due to its easy computation and quick understanding. Based on domain, image fusion divided into two: Spatial and transform domains. Fusion rule is directly applied to the pixel values of the source images in spatial domain. Example of spatial domain methods are averaging, weighted averaging and principal Component Analysis (PCA) [3]. Spatial domain approaches introduces some distortions in the resultant fused image and does not provide any spectral information. So, transform domain preferred in medical image field to overcome problem of spatial domain methods and produce fused image with enhanced quality [6].

In frequency domain, wavelet transforms are the mostly used for image fusion .In [1], Discrete Wavelet Transforms (DWT) have been used for medical fusion.. Image fusion is performed by decomposing source images into transformed coefficients followed by application of maximum fusion rules to the transformed coefficients. Fused image is obtained by inverse DWT. Rajiv singh et.al [2] have proposed multi scale fusion of multimodal medical images in frequency domain. Medical image fusion has been performed at many scales varying from minimum to maximum level .Fusion process is achieved by maximum fusion rule. .Finally, inverse wavelet transform is applied to obtain fused image.

This paper proposes a novel technique for medical image fusion in wavelet domain which is based on Lifting Wavelet Transform (LWT) .LWT is utilized in this work to decompose the source medical images. Then, the obtained coefficients are fused using three different fusion techniques namely Averaging, Average-Variance (AV) and Improved Average-Variance (IAV) technique to find the best method in wavelet domain. Inverse LWT (ILWT) is applied on the fused coefficients to reconstruct the fused image. The quantitative analysis of the medical image fusion results has been performed with Mutual Information (MI), Information Entropy (I*E*), standard deviation (STD), Correlation Coefficient (CC) Peak Signal to Noise Ratio (PSNR) and Signal to Noise Ratio (SNR).

The rest of the paper is organized as follows. Section 2 explains proposed medical image fusion method with three fusion technique .Image fusion results and evaluations are given in Section 3. Finally, conclusions of the work are given in Section 4 followed by relevant references.

II. PROPOSED MEDICAL IMAGE FUSION TECHNIQUE

Numerous image fusion techniques have been used for medical image fusion. Reviewing several papers, this paper preferred Lifting wavelet transform for medical image fusion. Different types of transform e.g. Curvelet transform [12]**,** contourlet transform which are also employed for medical image fusion provides better performance of fused image. But, these transforms are very expensive and dot not commonly used for medical image fusion purpose. The usefulness of LWT made it suitable for medical image fusion, where one wishes to capture all significant information from a single fused image with low cost, high accuracy and less complexity. The proposed medical image fusion framework is shown in Fig.1. LWT is easy and efficient method for medical image fusion. The proposed new medical image fusion with IAV fusion method provides fused image with high accuracy.

The detail steps of proposed medical image fusion technique are given below:

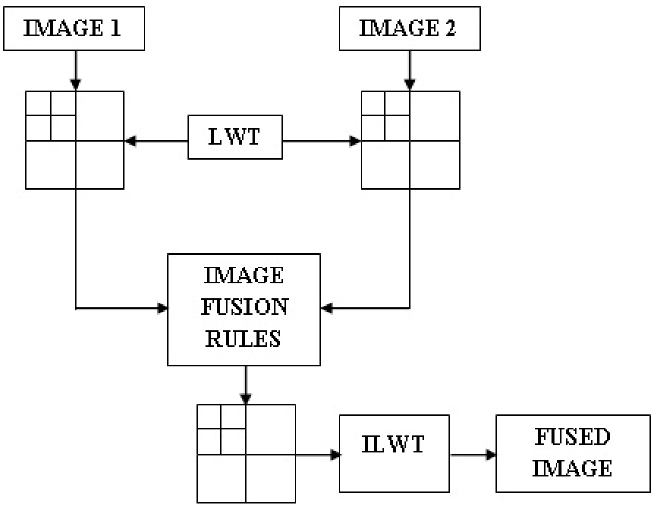

Figure 1: Framework for Medical Image Fusion in Wavelet Domain

Algorithm:

1. Read the first input image MRI/CT and find its size.
2. Read the second input image MRI/CT and find its size.
3. Input images are RGB image that to be separated to get intensity of each color in input images or convert the both the input image to gray scale image.
4. Compare size of both input images and make sure that the input images to be fused in same size.
5. Decompose the both input image using LWT upto n levels.
6. Select and apply the image fusion method for both the coefficients to obtain fused coefficients.
7. Apply ILWT on the fusion coefficients to obtain fused medical image.
8. Measure the performance of the proposed technique using some quantitative metrics and compare the effectiveness of fusion methods to find the suitable rule for image fusion.

A. Image Fusion Techniques

The input images CT and MRI are read first and converted to gray scale images. Decomposition level and wavelet type used are specified. In this work, Daubechies 4 is used for decomposition and reconstruction purpose. Then the decomposition is done on both images using LWT to find the approximation, horizontal, vertical and diagonal coefficients. The obtained coefficients are then fused using a specific image fusion method. Finally, fused coefficients are reconstructed back using ILWT. The proposed medical image fusion model uses three different fusion techniques for image fusion are as follows:

a) Averaging Technique

Averaging technique is a simple method of obtaining an output image with all regions in focus. After decomposition, the coefficients to be fused which employed the average method to get the approximation coefficient matrix of the fused image in the corresponding directions on approximation coefficient, and used the method of selecting a higher value in the corresponding directions on detailed coefficient[2][6]. For two source medical images A(x,y) and B(x,y), the steps of the averaging fusion technique are as follows.

(i) Decompose both the input images using LWT:

$$DecA_l(x,y) = LWT[A(x,y)]$$
$$DecB_l(x,y) = LWT[B(x,y)] \qquad (1)$$

Where, $DecA_l(x,y)$ and $DecB_l(x,y)$ are the wavelet coefficients of source images A (x, y) and B(x, y) at scale l.

(ii) Calculate fused wavelet coefficients FW_l at scale l by following the expression:

$$FW_l^{a}(x,y) = \{A(x,y) + B(x,y)\}/2$$
$$FW_l^{\xi}(x,y) = MAX[A(x,y), B(x,y)]_l^{\xi} \qquad (2)$$

Where, a-approximation coefficient and $\xi = (h,v,d)$ coefficients at scale l

(iii)Reconstruct fused image RF(x,y) at scale l using ILWT

$$RF_l(x,y) = ILWT[FW]_l \qquad (3)$$

b) Average-Variance Technique

In this technique, fused coefficients are obtained by applying averaging method on approximation coefficient and variance method on detailed coefficients [7]. Variance fusion takes pixel which has larger variance as fusion coefficient in detailed subband.

Variance of an image is defined as

$$V = \frac{1}{M * N} \sum_{p=1}^{M} \sum_{q=1}^{N} \left(x(p,q) - \bar{x} \right) \qquad (4)$$

$$FW_l^{\xi}(x,y)=\begin{cases} D^{\xi}{}_{l,A}(x,y) & V^{\xi}{}_{l,A} \geq V^{\xi}{}_{l,B} \\ D^{\xi}{}_{l,B}(x,y) & V^{\xi}{}_{l,A} < V^{\xi}{}_{l,B} \end{cases} \quad (5)$$

Where, V denotes the variance, M and N represent the number of rows and number of columns of an image

c) Improved Average-Variance technique

Normalized function of sources images are given below:

$$NV^{\xi}{}_{l,A} = \frac{V^{\xi}{}_{l,A}}{V^{\xi}{}_{l,A} + V^{\xi}{}_{l,B}} \quad (6)$$

$$NV^{\xi}{}_{l,B} = \frac{V^{\xi}{}_{l,B}}{V^{\xi}{}_{l,A} + V^{\xi}{}_{l,B}} \quad (7)$$

$$if \left|V^{\xi}{}_{l,A} - V^{\xi}_{l,B}\right| > TH$$

$$then$$

$$FD_l^{\xi} = \begin{cases} D_{l,A}^{\xi} & NV_{l,A}^{\xi} \geq NV_{l,B}^{\xi} \\ D_{l,B}^{\xi} & NV_{l,A}^{\xi} < NV_{l,B}^{\xi} \end{cases} \quad (8)$$

$$if \left|V^{\xi}{}_{l,A} - V^{\xi}_{l,B}\right| \leq TH$$

$$then$$

$$FD_l^{\xi} = NV_{l,A}^{\xi}.D_{l,A}^{\xi} + NV_{l,B}^{\xi}.D_{l,B}^{\xi} \quad (9)$$

Where, TH is the threshold

III.SIMULATION RESULTS

In this section, the paper presents medical image fusion results for the proposed three fusion techniques. The image fusion results have been shown for three sets of CT and MRI medical image pairs of size 256 × 256 shown in Figures 2(a)-2(e), 3(a)-3(e) and 4(a)-4(e) respectively. For objective evaluation of the proposed fusion techniques, shown from Figures 2–4, the paper have employed six fusion metrics such as Information Entropy (IE)[11],Mutual Information(MI)[9],Standard Deviation(STD) ,Correlation Coefficient(CC)[10], Peak Signal to Noise Ratio(PSNR) and Signal to Noise Ratio(SNR)[8].Higher values of these parameters indicates better fused result. Performance of proposed three fusion techniques result is tabulated in table 1.

On observing Table 1, one can easily found that the fusion measures for proposed improved average-variance fusion technique have higher values of fusion metrics than averaging and average-variance fusion techniques. However, the improved average-variance fusion technique has lesser values of STD and IE than other two methods. For these cases, the paper performed an overall comparison in Table 1 and it states that the proposed improved average-variance fusion.

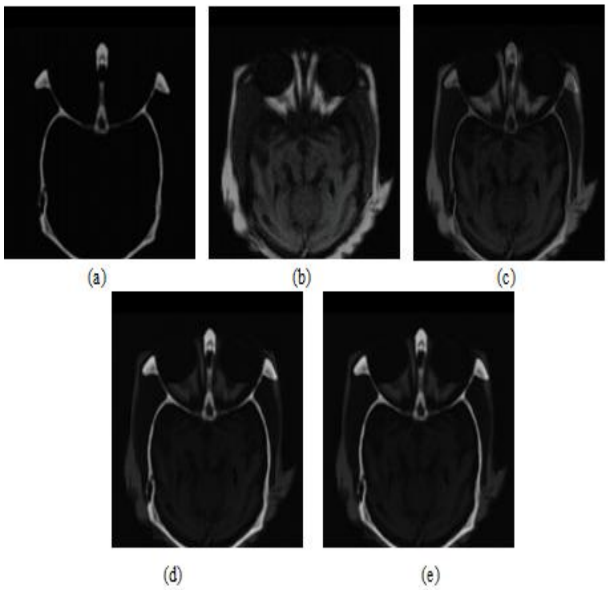

Figure.2.Fusion results of medical images.(a) CT image (b) MRI image (c)Averaging fusion (d)Average-Variance fusion (e)Improved average- variance fusion

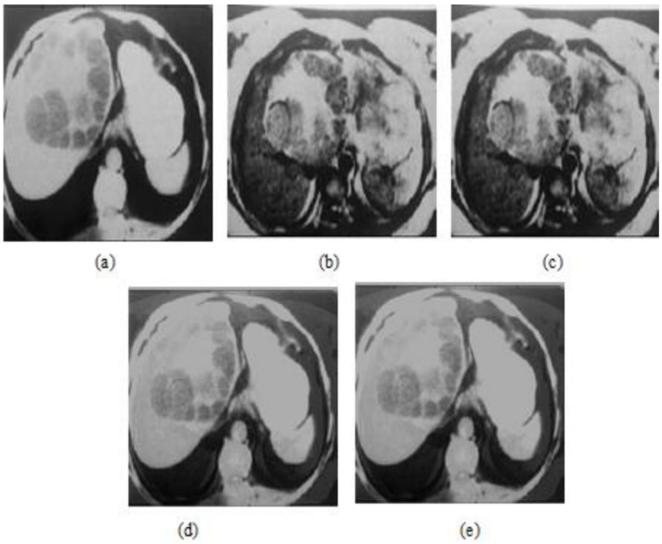

Figure.3.Fusion results of medical images.(a) CT image (b) MRI image (c)Averaging fusion (d)Average-Variance fusion (e)Improved average- variance fusion

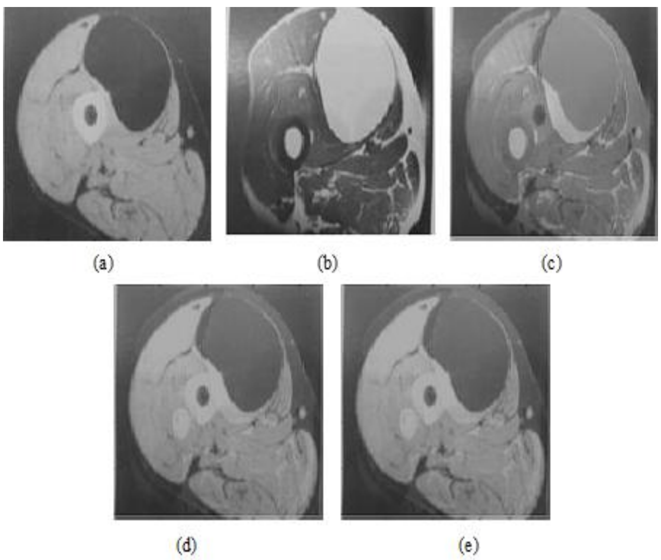

Figure.4.Fusion results of medical images.(a) CT image (b) MRI image (c)Averaging fusion (d)Average-Variance fusion (e)Improved average- variance fusion

Table 1: Quantitative Evaluation of Fusion Results

Data set	Technique	MI	STD	IE	CC	PSNR	SNR
Data set 1	Averaging	6.881	16.108	5.119	0.602	32.88	1.052
	Variance	6.896	19.335	4.758	0.949	37.254	0.822
	Improved variance	6.906	19.153	4.631	0.954	37.349	0.824
Data set 2	Averaging	14.96	45.933	7.446	0.743	31.162	2.504
	Variance	14.96	77.044	6.81	0.978	35.726	2.265
	Improved variance	14.961	76.836	6.8	0.98	35.899	2.27
Data set 3	Averaging	14.314	27.066	6.942	0.531	32.251	4.12
	Variance	14.314	40.836	7.306	0.953	36.747	4.022
	Improved variance	14.314	40.752	7.305	0.954	36.797	4.027

MI - Mutual Information, IE -Information Entropy's, STD - Standard Deviation ,CC-Correlation Coefficient ,PSNR-Peak Signal to Noise Ratio and SNR-Signal to Noise Ratio technique has better performance for the last two set of medical images.

CONCLUSIONS

This presents a new medical image fusion method for multimodal images in frequency domain and employed LWT for proposed fusion scheme. The multimodal medical images are fused at specified scale using three fusion methods. To evaluate the effectiveness of the proposed method and comparative analysis of the fusion results, we have used six metrics. From the results it is found that the improved average-variance technique is better than other two techniques.

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