Image Fusion On Mr And Ct Images Using Wavelet Transforms And Dsp Processor

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***Abstract*— Medical image fusion is a technique in which useful information from two or more recorded medical images is integrated into a new image. It can be used to make clinical diagnosis and treatment more accurate. Wavelet transform fusion considers the wavelet transforms of the two registered source images together with the fusion rule. The fused image is reconstructed when the inverse wavelet transform is computed. Usually, if only a wavelet transformation is applied, the outcomes are not so helpful for analysis. But, better fusion results may be attained if a wavelet transform and a traditional transform such as Principal Component Analysis (PCA) transform is integrated. Hence a new novel approach is introduced in this work to improve the fusion method by integrating with PCA transforms. Haar wavelet decomposes a signal into frequency sub-band at different scale from which registered image can be perfectly reconstructed. As stated above, the Hardware support results show that the scheme can preserve all useful information from primal images in addition the clarity and the contrast of the fused image are improved.**

***Keywords*— Fusion, Wavelets, PCA Transform,Haar transform, Blackfin DSP processor**

I. INTRODUCTION

Image fusion is a device to integrate multimodal images by using image processing techniques. Specifically it aims at the integration of disparate and complementary data in order to enhance the information visible in the images. It also increases the reliability of the interpretation consequently leads to more accurate data and increased utility. Besides, it has been stated that fused data gives for robust operational performance such as increased confidence, reduced ambiguity, improved reliability and improved classification [1, 2, 3, 4].

The prime objective of medical imaging is to get a high resolution image with as much details as possible for the accurate diagnosis [7]. CT gives best information about denser tissue and MR provides better information on soft tissue [2, 10, and 4]. Both the techniques give special refined characteristics of the organ to be imaged. So, it is desired that fusion of MR and CT images of the same organ would result in an integrated image with detail information [10]. In 1982, Jean Morlet introduced the idea of the wavelet transform. The wavelet transform decomposes the image into low-high, high-low and high-high spatial frequency bands at different scales and the low-low band at the coarsest scale. The L-L band contains the average image information whereas the other bands contain directional information due to spatial orientation. Higher absolute values of wavelet coefficients in the high bands correspond to salient features such as edges or lines[1,2,4,6,10].

The image fusion methods may not be satisfactory to combine a high-resolution panchromatic image and a low-resolution multispectral image because they can distort the spectral characteristics of the multispectral data. The proposed integer wavelet transform and principal component analysis (*PCA*) can be used to generate spectrum-preserving high-resolution multispectral images. In addition, the fused multispectral images are simultaneously found via only one wavelet transform[2,4,11,12,14].

The work anticipated in this paper uses haar wavelet. It is fastest to compute and simplest to execute. The main advantages are, it can be calculated in place without a temporary array as it is memory efficient. And it is exactly reversible without the edge effects which is a problem with other wavelet transforms [5,8,9,13].

The DSP Processors such as ADSP-BF533/32/31 processors are enhanced members of the Blackfin processor family. They offer significantly higher performance and lower power than previous Blackfin processors while retaining their ease-of-use and code compatibility benefits. The processors are completely code and pin-compatible, differing only with respect to their performance and on-chip memory [15,16].

II.WAVELET TRANSFORM

The coefficients at the course level in the wavelet transform represent a larger time interval but a narrower band of frequencies. This characteristic of the wavelet transform is very vital for image coding. In the active areas, the image data is more restricted in the spatial domain, whereas in the smooth areas, the image data is more localized in the frequency domain., It is very hard to reach a good compromise with traditional transform coding.

Due to its nice multi-resolution properties and decoupling characteristics, Wavelet transform has been used for various image analysis problems. The stated algorithm utilizes the advantages of wavelet transforms for image enhancement. Mostly Wavelet transform has been used as a fine image representation and analysis tool due to its multi-resolution analysis, data reparability, compaction and sparsely features over and above statistical properties. A wavelet function (t) is a small wave, which must be oscillatory in some way to differentiate between different frequencies. The wavelet consists of both the analysing shape and the window. We applied the two-level wavelet transformation to separate an image into three frequency components: high, medium and low in order to observe the degree of influence of image textural on the reconstructed composition.

A. Wavelet Based Image Fusion

The start of multi-resolution wavelet transforms gave increase to extensive development in image fusion research. For various applications utilizing the directionality, orthogonality and compactness of wavelets, numerous methods were proposed. All significant analysis information in the image should be kept by fusion process. It should not bring in any artefacts or discrepancy while suppressing the undesirable characteristics like noise and other irrelevant details.

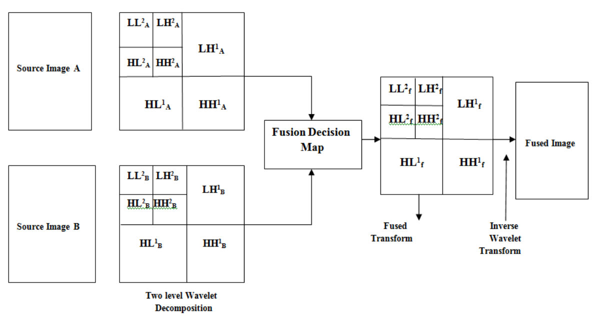


Fig. 1 Wavelet based image fusion

The DWT is applied for both the source images and decomposition of each original image is achieved. This is embodied in the multi-scale illustration where different bars (horizontal, vertical, diagonal and null) represent different coefficient. There are two decomposition levels, as it is shown in the left upper sub image. The different black boxes connected to each decomposition level are coefficient related to the same image spatial representation in each original image that is the same pixel positions in the original image. Only coefficients of the same level and representation are to be fused. Once the fused multi-scale is obtained, through IDWT the final fused image is achieved.

B. Wavelet Based Image Fusion Techniques

In the field of image processing, the wavelet transform is a superior mathematical tool developed. The wavelet coefficients for each level include the spatial (detail) differences between two successive resolution levels. The most important benefit of the wavelet based fusion method lies in the minimal distortion of the spectral characteristics in the fusing result.

1. Additive wavelet based image fusion method

The method can be divided into four steps:

Step 1- Apply the histogram match process between panchromatic image and different bands of the multispectral image respectively. And three new panchromatic images PAN_R, PAN_G, PAN_B can be obtained

Step 2- Make use of the wavelet transform to decompose new panchromatic images and different bands of multispectral image twice, respectively.

Step 3- Add the detail images of the decomposed panchromatic images at different levels to the corresponding details of different bands in the multispectral image and obtain the new details component in the different bands of the multispectral image.

Step 4- Carry out the wavelet transform on the bands of multispectral images, respectively and obtain the fused image.

2. Integration of substitution method

The integration of substitution method is divided in two parts.

a. Refers to substitution fusion method.
b. Refers to the wavelet passed fusion method.

The process consists of following steps

- Transform the multispectral image into the PCA component.
- Apply histogram match between panchromatic image and intensity component and obtain new panchromatic image.
- Decompose the histogram matched panchromatic image and intensity component to wavelet planes respectively.
- Replace the LL^P in the panchromatic decomposition with the LL^1 of the intensity decomposition, add the detail images in the panchromatic decomposition to the corresponding detail image in the panchromatic decomposition to the corresponding detail images of the intensity and obtain LL^1, LH^P ,HH^P and HL^P.Perform an inverse wavelet transform, and generate a new intensity. Transform the new intensity together with hue, saturation components or PC1, PC2, PC3 back. Into RGB space.

C. Types Of Wavelet Transforms

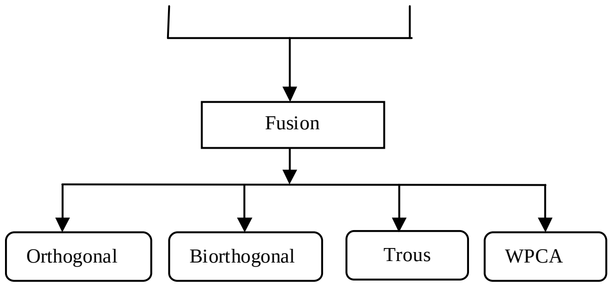


Fig.2 Type of Wavelet Transform

As stated in the fig.2, the wavelets used in image fusion can be categorized into three general classes: orthogonal, biorthogonal and Trous. Each wavelet has unique image decomposition and reconstruction characteristic that leads to different fusion results even though these wavelets share some common properties.

1) Orthogonal Wavelet

The dilations and translation of the scaling function Øj,k(x) constitute a basis for Vj, and similarly ψj,k(x) for Wj, if the Øj,k(x) and ψj,k(x) are orthogonal. They include the following property.

$$V_j \perp W_j$$

The orthogonal property lays a strong limitation on the construction of wavelets. For example, it is hard to find any wavelets that are compactly supported, symmetric and orthogonal.

2) Biorthogonal wavelet

Perfect reconstruction is available for biorthogonal transform. Orthogonal matrices and unitary transforms are given by orthogonal wavelets whereas invertible matrices and perfect reconstruction are given by biorthogonal wavelets. For biorthogonal wavelet filter, the Low – pass and high – pass filters do not have the same length. The former is always Symmetrical, while the later could be either symmetric or anti – symmetric.

3) A 'trous' wavelet (non – orthogonal wavelet)

A trous is a type of non – orthogonal wavelt. Thu, it is different from orthogonal and biorthogonal. It is a 'stationary' or redundant transform, i.e. decimation is not implemented during the process of wavelet transform. On the other hand, the orthogonal or biorthogonal wavelet can be carried out using either decimation or undecimation mode.

III. PRINCIPAL COMPONENT ANALYSIS

The WPCA approach decomposes an image of size (M x N) pixels into a set of a x b multivariate processing units. Therefore, an original image has g x h (i.e. M/ax N/b) multivariate processing units. For each multivariate processing unit, the region of size a x b pixels can be applied the wavelet transform to get four wavelet characteristics A, D1, D2 and D3 through calculations. The PCA integrates the multiple wavelet characteristics into a PC score for each multivariate processing unit. This PC score can be regarded as a distance value of a multivariate processing unit. If the PC score is large, the difference between the region and normal area will be more. Consequently, this region can be judged as a defective region. Or else, this region has no defect.

Traditional PCA image fusion consists of four steps:

(i) Geo metric registration can format that size of low -resolution multi -spectral images which is the same as the high re solution image.

(ii) By PCA transformation, transforming low -resolution multi -spectral images to the principal component images.

(iii) Replacing the first principal component image with the high-resolution image that is stretched to have approximately the similar variance and mean as the first principal component image.

(iv) Before the data are back transformed into the original space by PCA inverse transformation, the results of the stretched PAN data replace the first principal component image.

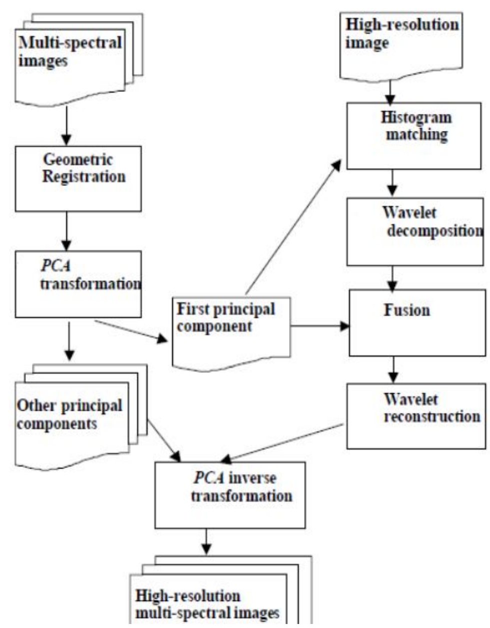


Fig.3 The flow chart of the wave let-based PCA method

As shown in the above fig.3, the standard PCA image fusion and the wavelet -based image fusion are combine to propose wavelet -based PCA image fusion which improves the traditional PCA image fusion.

This method consists of seven steps: geometric registration, PCA transformation, histogram matching, wavelet decomposition, fusion, wavelet reconstruction, and PCA inverse transformation.

In study, an image fusion approach is proposed to enhance the spatial quality of the multispectral images while preserving its spectral contents to a greater extent. High resolution Multispectral image with high PSNR ratio have been obtained by fusing low resolution multispectral image and high resolution PAN image.

A. WPCA Algorithm Steps

1. Representation of training images
Obtain face images A1, A2…AM for training. Every image must of the same size (N×N).

2. Computation of the mean image
The images must be mean centered. By adding the corresponding pixels from each image, the pixel intensities of the mean face image are obtained. The mean image can be calculated as

$$m=1/M \text{™} \Sigma_{c=1}^{M} A_c$$

3. Normalization Process of Each Image in the Database
Subtract the mean image from the training images.

$$\bar{A}=A_c-m \quad \text{where, } c=1 \text{ to } M$$

4. Calculation of Covariance Matrix
The covariance matrix, which is of the order of N×N, is calculated as given by

$$C=1/M \, \Sigma^{M} (A-m)^T(A-m)_{c=1}$$

5. Calculation of Eigen values and Eigen vectors
Find the eigen values of the covariance matrix C by solving the equation $(C\lambda\text{-}I)=0$ to calculate the eigen values $\lambda 1, \lambda 2 \ldots \lambda N$.

For specific eigen value $\lambda 1$ solve the system of N equations

$$(C\lambda\text{-}I)=0$$

To find the eigen vector X Repeat the procedure for N eigen values to find X1 …Xn eigen vectors. The relation between Eigen vectors and eigen value is given as XiT(AAT)Xt=λt. Where Xi indicates the Eigen vectors and λi indicates corresponding Eigen values.

6. Sorting the Eigen values and Eigen vectors
The Eigen vectors are sorted according to corresponding eigen values in descending order. The Eigen vector associated with the largest eigen value is one that reflects the largest variance in the image.

7. Choosing the best 'k' Eigen Vectors
Keep only 'k' eigenvectors corresponding to the 'k' largest eigen values. Each face in the training set can be represented as a linear combination of the best 'k' eigenvectors.

IV. HAAR WAVELET TRANSFORM

The Discrete Wavelet Transform (DWT) of image signals produces a non-redundant image representation. If compared with other multi scale representations such as Gaussian and Laplacian pyramid, it provides better spatial and spectral localization of image formation. In recent times, the more and more interest in image processing has been attracted by Discrete Wavelet Transform. It can be interpreted as signal decomposition in a set of independent, spatially oriented frequency channels. The signal S is passed through two complementary filters and appears as two signals, approximation and details which are called decomposition or analysis process. Without loss of information, the components can be assembled back into the original signal which is called reconstruction or synthesis process. The mathematical operation, which entails analysis and synthesis, is called discrete wavelet transform and inverse discrete wavelet transform. By using DWT, an image can be decomposed into a sequence of different spatial resolution images. An N level decomposition can be performed resulting in 3N+1 different frequency bands in case of 2D image namely, LL, LH, HL and HH. Bands are also known by further names, the sub-bands may be respectively called a1 or the first average image, h1 called horizontal fluctuation, v1 called vertical fluctuation and d1 called the first diagonal fluctuation. The sub-image a1 is created by computing the trends along rows of the image followed by computing trends along its columns. In the same way, fluctuations are also formed by computing trends along rows followed by trends along columns. The next level of wavelet transform is applied to the low frequency sub-band image LL only. The Gaussian noise will nearly be averaged out in low frequency wavelet coefficients. So, only the wavelet coefficients in the high frequency levels need to be threshold.

The Haar wavelet is irregular and similar to a step function. For a function **f**, the HWT is defined as:

$$f \rightarrow (a^L \mid d^L)$$
$$a^L = (a_1, a_2, \ldots, a_{N/2})$$
$$d^L = (d_1, d_2, \ldots, d_{N/2})$$

Where L = decomposition level,
a =approximation sub-band and
d = detail sub-band.

$$a_m = \frac{f_{2m} + f_{2m-1}}{\sqrt{2}} \qquad for\ m = 1,2, \ldots, N/2$$

$$d_m = \frac{f_{2m} - f_{2m-1}}{\sqrt{2}} \qquad for\ m = 1,2, \ldots, N/2$$

Apply a one level Haar wavelet to each row and secondly to each column of the resulting 'image' of the first operation to apply HWT on images. The result image is decomposed into four sub-bands which contain an approximation of the original image while the other sub-bands include the missing details. The LL- sub-band output from any stage can be decomposed further.

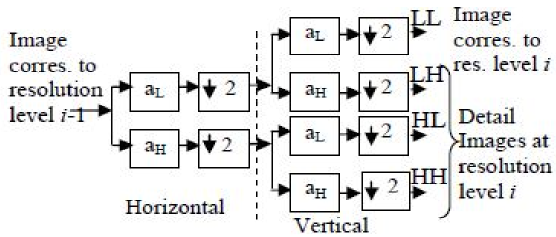
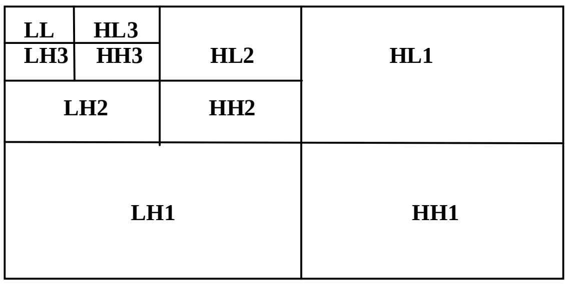


Fig.4 One Filter Stage in 2D DWT



Structure of wavelet decomposition

Inverse Haar Wavelet transform (IHWT)

The inverse of the HWT is calculated in the reverse order as follows:

$$\mathbf{f} = \left(\frac{a_1 - d_1}{\sqrt{2}}, \frac{a_1 + d_1}{\sqrt{2}}, \ldots, \frac{a_{N/2} - d_{N/2}}{\sqrt{2}}, \frac{a_{N/2} + d_{N/2}}{\sqrt{2}}\right)$$

Here, a one level inverse Haar wavelet is applied to each column and secondly to each row of the resultin “image” of the first operation to apply IHWT on images.
They are not shift invariants and consequently the fusion methods using DWT produce unsteady and flickering results. For the case of image sequences, the fusion process should not be dependent on the location of an object in the image. The fusion output should be stable and consistent with the original input sequence. Haar wavelet transform are used to make the DWT shift invariant. Haar wavelets are real, orthogonal and symmetric.

A. Proposed Algorithm

In this paper, CT and MR images are considered as input images for image fusion. The proposed algorithm is as follows.

- Each source image is resampled that is preprocessing is done at first. The pixel dimensions of an image are changed by resampling. This process does not alter the gray level value. A nearest neighbor interpolation is preferred if variations in the gray levels need to be maintained.

- Since Haar wavelet is used, this method is believed as the most efficient in terms of computation time

- To obtain the decimated coefficients, Haar wavelet transform is applied on the each source image. The source images are subjected to decomposition and the resulting coefficients are evaluated.

- The fusion is performed by applying fusion rule and the fused image is acquired.

- This fused image is reconstructed using inverse transform and quality metrics are calculated and analyzed.

The proposed algorithm is shown in the following figure.

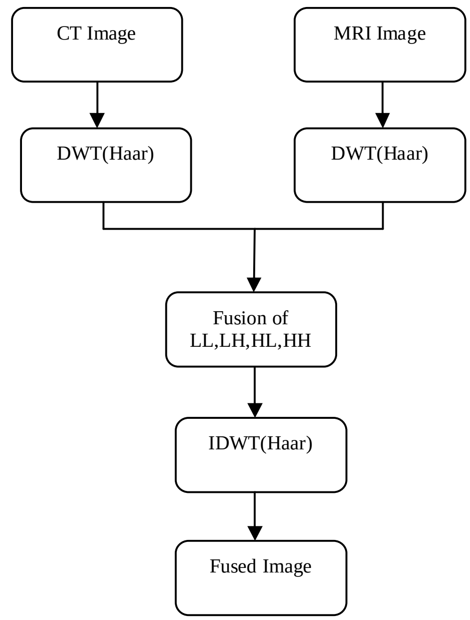


Fig.5 Proposed Haar Transform algorithm

V HARDWARE SUPPORT

The Blackfin Evaluation Board is specially devised for developers in DSP field as well as beginners. The BF532 kit is devised in such way that all the possible features of the DSP will be easily used by everyone. The kit supports in VisualDsp++5.0 and later.

The followings are playing a major in our hardware support:

- BF532 KIT with 128Mbit SDRAM, 1Mbyte FLASH & UART
- Visual Dsp++
- MATLAB.

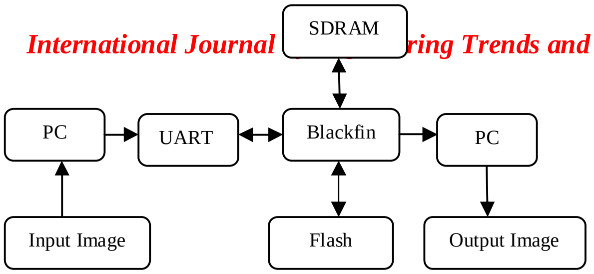


Fig. 6 The flow diagram of proposed system

Step1**.** The Blackfin Evaluation Board has 128Mbit SDRAM interfaced in BF532 kit. This interface will be used to store a huge data (pixel).
Step2. The RS2329 pin serial communication is interfaced through UART Serial Interface peripheral. This interface is used to communicate kit with the Matlab.
Step3. The Visual Dsp++ will help to do the source code for Blackfin 532 to implement the Image Fusion algorithm and to debug.
Step4**.** The MatLab R2010a will help to see images on GUI Window from processor UART through pc.

VI. EXPERIMENTAL RESULTS

In the MRI image, the inner contour misses but it gives better information on soft tissue. In the CT image, it provides the best information on denser tissue with less distortion, but it misses the soft tissue information.

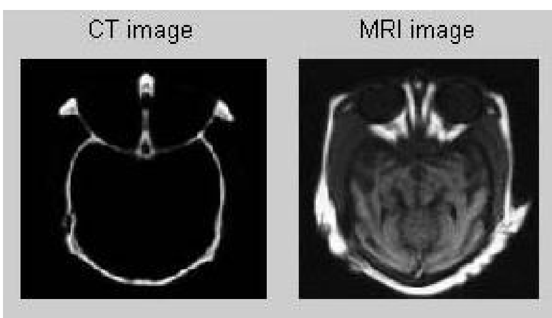


Fig.7 Input Image1 and input Image2 represents the CT and MRI images of Brain of same person respectively

Here, type of wavelet transforms is applied for the fusion process. The comparative analysis is made based on MSE, PSNR & Entropy.

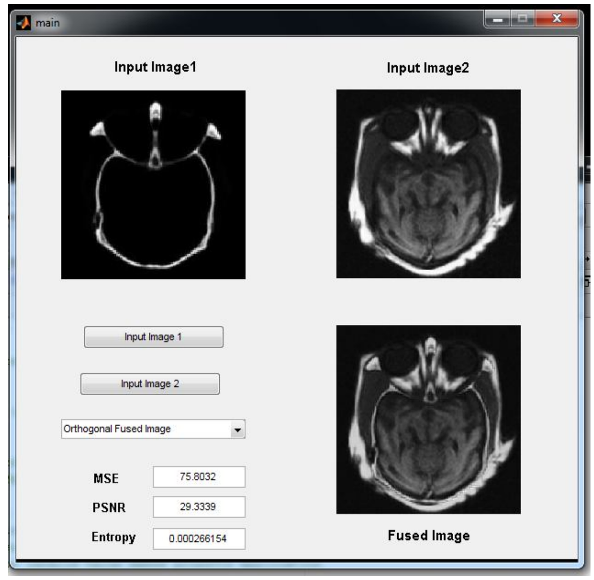


Fig.8 Orthogonal fused image

As shown in the above image, it is the result of orthogonal wavelet fusion technique which is by combining of MRI and CT images. The orthogonal wavelet fused image contains information of both images but have more aliasing effect.

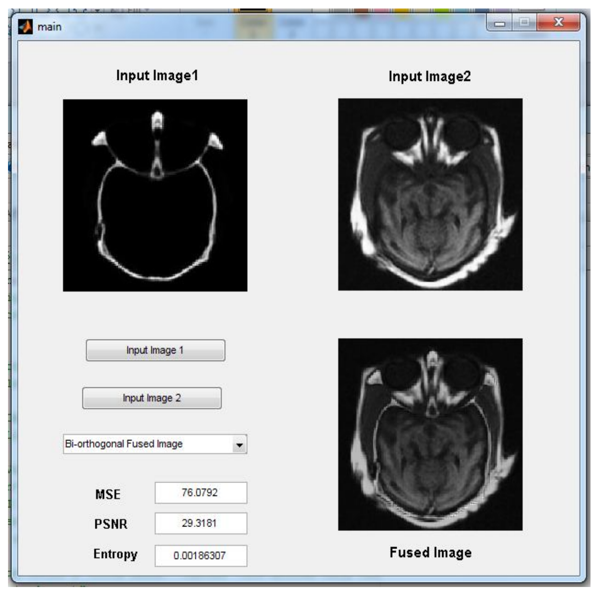


Fig.9 Biorthogonal fused image

As shown in the above image, it is the result of Biorthogonal wavelet fusion technique. When compare Biorthogonal wavelet with orthogonal wavelet, it demonstrates soft tissues information which is not shown in above figure explicitly at the left and right side of the inner part.

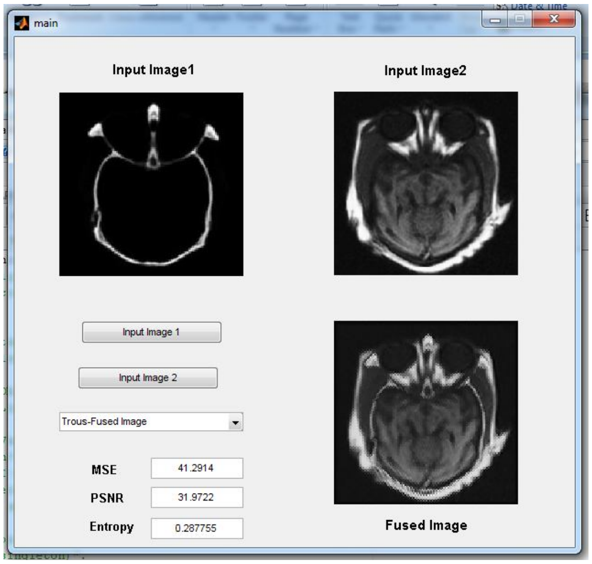


Fig.10 ‘A trous’ wavelet fused image

As shown in the above image, it is the result of ‘A trous’ wavelet (non-orthogonal wavelet) fusion technique. The fusion result of non-orthogonal wavelet provides information on soft tissues and denser tissues.

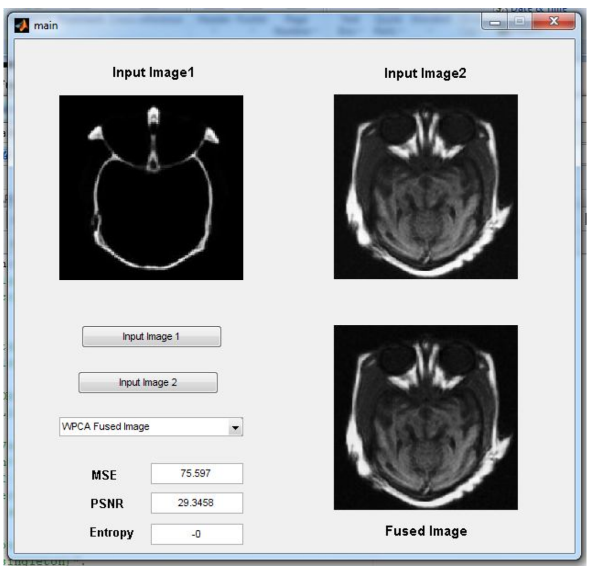


Fig.11 WPCA fused image

As shown in the above image, it is the result of WPCA transform, which shows that the WPCA Method gives the more information on soft tissues and denser tissues. Thus, it is cleared that the WPCA is better fusion method from a spatial and spectral information perspective.

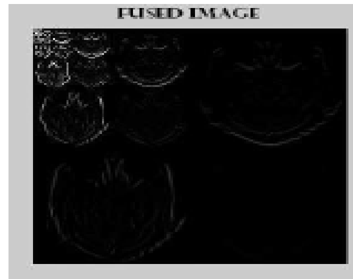


Fig.12 decomposition of fused image

Figure.12 represents level decomposition of fused image in our proposed Haar Transform method.

Fig.13 Reconstructed Image used Haar Transform

As shown in the above figure, reconstructed image is exactly reversible without the edge effects that are a problem with other wavelet transforms. The following table exhibits the statistical parameters of reconstructed images.

Parameter Type	MES	PSNR	Entropy
Haar Wavelet	8.1567	39.0157	1.7767

The statistical parameters are Mean Square Error, Signal to Noise Ratio and Entropy. The above table indicates that the proposed technique surpasses the other wavelet approaches. From the table, it can be observed that the proposed method has less Mean Square Error and high Signal to Noise Ratio compared to other methods.

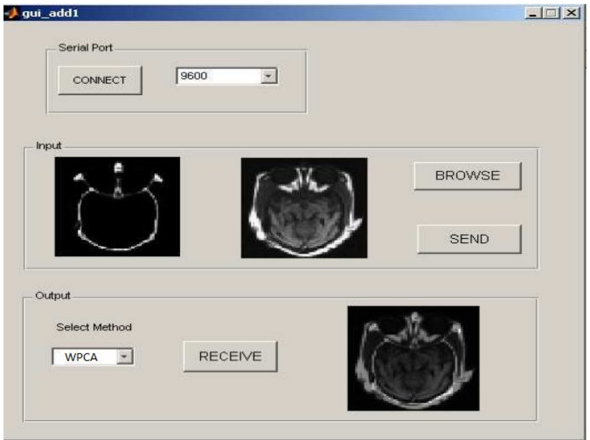


Fig.14 Proposed Hardware support Accepting fuse image

VII. CONCLUSION

Fusion imaging is one of the most modern, accurate and useful diagnostic techniques in medical imaging today. In this paper, the integration of wavelets and PCA for the fusion of magnetic resonance and computed tomography medical images has been proposed. Haar wavelet transform is applied to decimate each source image. The resulting coefficients are fused and reconstructed using inverse wavelet transforms. From the statistical analysis, it is proved that the harr wavelet is more suitable for medical image fusion, since it provides less MSE and high SNR than Orthogonal, Biorthogonal, Trous and PCA wavelets. From the simulation results, it is obvious that the resultant fused image consists of information about both soft and dense tissues and free from undesirable effects. The proposed technique is going to implement on the processor based kit or show the hardware support.

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