

# VLSI Implementation of Medical Image Fusion Using Haar Transform

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**Abstract** - Now-a-days, almost all areas of medical diagnosis are impacted by the digital image processing. When an image is processed for visual interpretation, the human eye is the judge of how well a particular method works. Clinical application demanding Radiotherapy plan, for instance, often benefits from the complementary information in images of different modalities. For medical diagnosis, Computed Tomography (CT) provides the best information on denser tissue with less distortion. Magnetic Resonance Image (MRI) provides better information on soft tissue with more distortion. With more available multimodality medical images in clinical applications, the idea of combining images from different modalities become very important and medical image fusion has emerged as a new promising research field. The experiments show that the method could extract useful information from source images to fused images so that clear images are obtained.

In this paper, a hardware implementation of a image fusion system is proposed. Here MATLAB is used to convert images into pixel-format files and to observe simulation results. To implement this paper XPS & VB are needed. In XPS, first select hardware & software components then by adding source and header files & converting into bit streams and download into FPGA, to obtain fused image.

**Index terms** - Fusion, Wavelets Transform, XPS, GUI and FPGA.

## 1 INTRODUCTION

Image fusion is the process of combining relevant information from two or more images into a single image. Then the resultant image have more information has more information than input images. Image fusion has become a topic of great interest to the engineers working in different domains. It's being used for medical applications, so as to get a better image. It's also being used in automotive industries to enhance the vision of road, to observe a better image during a rainy or foggy weather.

Due to the increasing number of high-resolution images are available along with sensor technology development, image fusion is still a popular and important method to interpret the image data for obtaining a more suitable image for a variety of applications, such as visual interpretation, digital classification [1], satellite & war-field.

The main objective of medical imaging is to obtain a high resolution image with as much details as possible for the sake of diagnosis [2]. MRI and CT imaging are of main concern for diagnostic purposes [3]. Both techniques give special sophisticated characteristics of the organ to be imaged. So, it is expected that fusion of MRI and CT images of the same organ would result in an integrated image of much more information [4].

Wavelet transform fusion is defined as considering the wavelet transforms [5] of the two registered input images together with the fusion rule. Then, the inverse wavelet transform is computed, and the fused image is reconstructed.

Generally the image fusion [6] process can be carried out at various levels. Under this, in the pixel-level image fusion the

fused images provided all relevant information present in original images without any inconsistencies.

The pixel-level image fusions were classified into spatial domain fusion and transform domain fusion. Spatial domain fusion is directly applied on the source images which in turn reduce the signal to-noise ratio of the resultant image with simple averaging technique but the spatial distortion still persists in the fused image. To improve on that in transform domain fusion, firstly the input images are decomposed into some levels based on transform coefficients. Then the fusion technique is applied and the fusion decision map is obtained. Inverse transformation on this decision map yields the fused image. The fused image includes all the details of the source images and reduces the spatial distortion. So, majority of the earlier fusion techniques were based on wavelet transformation.

### 1.1 Wavelet Transform

Wavelets are mathematical functions define over a finite interval and it has zero average value, which transforms data into different frequencies, to represent each component with a resolution matched to its scale. Wavelets have advantages over Fourier methods in analyzing physical situations, where the signal contains discontinuities and sharp spikes. It can also be used to decompose two dimensional (2D) signals such as 2D gray-scale image signals into different resolution levels for multi-resolution analysis Wavelet transform has been greatly used in many areas, such as texture analysis, data compression, feature detection and image fusion.

Wavelet transform fusion schemes offer several advantages over similar pyramid based fusion schemes when it comes to image fusion:

- The wavelet transform provides directional information while the pyramid representation doesn't introduce any spatial orientation in the decomposition process.
- In pyramid based image fusion, the fused images often contain blocking effects in the regions where the input images are significantly different. No such artefacts are observed in similar wavelet based fusion results.
- The images generated by wavelet image fusion have better signal-to-noise ratios (SNR) than images generated by pyramid image fusion when the same fusion results are used.

## 2 PROPOSED METHOD

The Discrete Wavelet Transform [7] was developed to apply the wavelet transform to the digital world. Filter banks are used to approximate the behaviour of the continuous wavelet transform. The signal is decomposed with a high-pass filter and a low-pass filter. The coefficients of these filters are computed using mathematical analysis and available in subsections.

### 2.1 Wavelet Transform for Fusing Images

In this subsection, the detailed fusion steps based on wavelet transform can be summarized below.

1. First register the input images (I1 and I2), which are going to be fused and corresponding pixels are aligned.
2. The Registered input images are decomposed into wavelet transformed images respectively, based on haar wavelet transformation (W). The transformed images with K-level decomposition will include one low-frequency portion (LL band) and 3K high-frequency portions (LH bands, HL bands and HH bands).

3. The Transform coefficients of different portions are performed with a certain fusion rule.
4. Then by applying performing an inverse wavelet transform ( $W^{-1}$ ) based on the combined transform coefficients, the fused image (I) is constructed.

### 2.2 Wavelet Decomposition of Images

Filter banks decompose the signal into high- and low-frequency components. The low-frequency component usually contains most of the frequency of the signal. This is called the approximation. The high-frequency component contains the *details* of the signal. Wavelet decomposition can be implemented using a two-channel filter bank.

In wavelet decomposing of an image, the decomposition is done row by row and then column by column. For instance, here is the procedure for an  $N \times M$  image. Then filter each row and down-sample to obtain two  $N \times (M/2)$  images, they are L and H images. The formulas used to do find H and L is given below.

$$H = \text{odd-even} = F_1;$$

$$L = \text{even} + \text{round}(F_1/2);$$

Then filter each column and subsample the filter output to obtain four  $(N/2) \times (M/2)$  images, by using the formulas shown in below.

$$LH = \text{odd} - \text{even} = F_2;$$

$$LL = \text{even} + \text{round}(F_2/2);$$

$$HH = \text{odd} - \text{even} = F_3;$$

$$HL = \text{even} + \text{round}(F_3/2);$$

The four sub-images obtained as seen in Fig. 1, the one obtained by low-pass filtering the rows and columns is referred to as the LL image. Similarly LH, HL and HL are also formed. Each of the sub images obtained in this fashion can then be filtered and subsample to obtain four more sub images. This process can be continued until the desired sub band structure is obtained.

- In the structure of pyramid decomposition, only the LL sub image is decomposed after each decomposition into four more sub images.
- In the structure of wavelet decomposition, each sub image (LL, LH, HL and HH) is decomposed after each decomposition.
- In the structure of space, after the first level of decomposition, each sub image is decomposed into

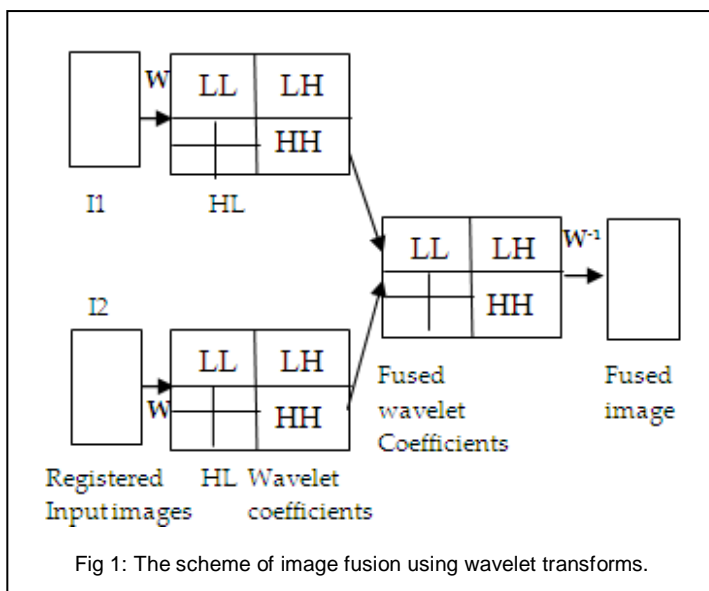


Fig 1: The scheme of image fusion using wavelet transforms.

smaller sub images, and then only the LL sub image is decomposed.

### 2.3 Wavelet Reconstruction Filter Banks

The input and the reconstruction are identical, this is called perfect reconstruction. Two popular decomposition structures are *pyramid* and *wavelet transform*. The first one decomposes only the approximation (low-frequency component) part while the second one decomposes both the approximation and the detail (high-frequency component).

It is possible to reconstruct the original signal from the coefficients of the approximations and details. The process yields a reconstructed approximation which has the same length as the original signal and which is a real approximation of it. The wavelet analysis involves filtering & down-sampling, whereas the wavelet reconstruction process consists of up-sampling and filtering. The reconstruction of the image is achieved by applying the inverse discrete wavelet transform (IDWT). The values are up-sampled and then passed to the filters.

## 3 IMPLEMENTATION PROCESS

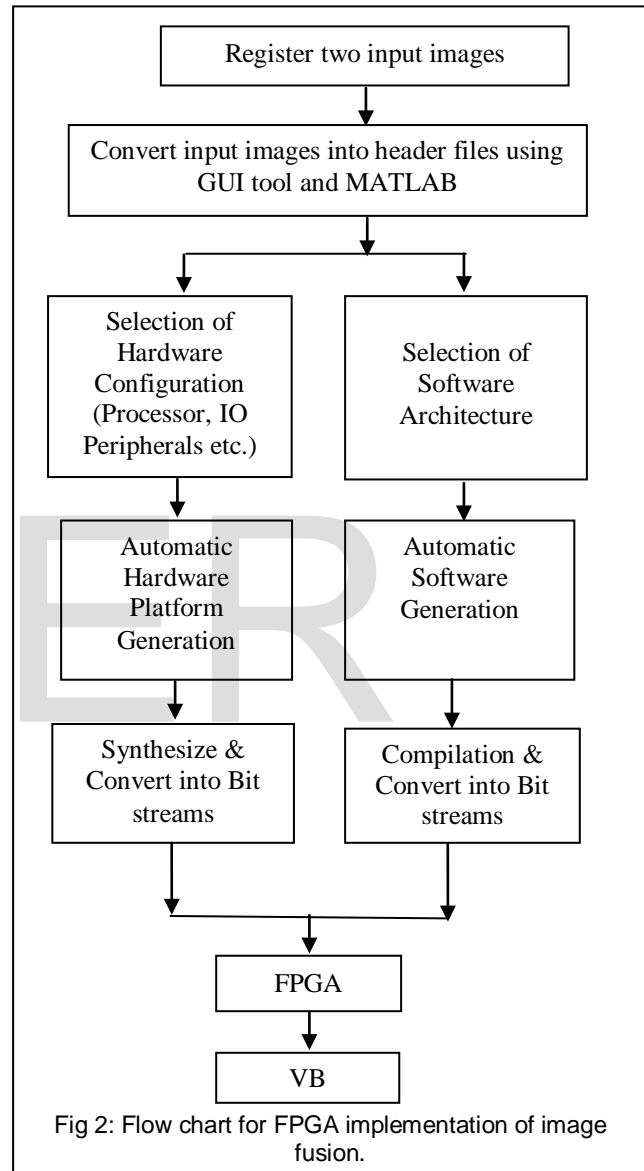
The implementation steps of the image fusion using DWT is done as follows. MATLAB is used to convert input images into header files using GUI feature. Xilinx Platform Studio (XPS) is a part of an EDK system and it includes the XPS-GUI and all tools run by the GUI to process hardware & software components within XPS. FPGA hardware is chosen because of it has some advantages like reconfigurability, low power dissipation, small size.

Fig.2 shows the flowchart for the implementation of image fusion using haar wavelet transform. The process is done as per below.

*Step 1:* First Select the Hardware configuration like processor, IO peripherals etc. The HDL codes are generated automatically for the each specified hardware selection and then convert it into bit streams.

*Step 2:* After that the selection of software architecture is started. It selects drivers, libraries etc. the header files of input images and source file (which consist of DWT, fusion and IDWT code written in the system-C language) are added and convert it into bit stream.

*Step 3:* Then download hardware and software architecture bit streams into FPGA and run it. The image output can't be shown in FPGA. For this purpose Visual Basic is used to observe the fused image output.



## 4 RESULTS

### 4.1 Simulation Results

In the proposed algorithm, mainly focussed on the medical application i.e., image fusion of CT and MRI images. First the input images are converted into header files in the MATLAB with the use of GUI function.

The implementation process of GUI involves 2 tasks, which are

- Laying out the GUI components
- Programming the GUI components.

First create GUI window by the use of pushbuttons and axes. By saving that window it automatically generates the MATLAB file, and then writes a MATLAB code at the respective pushbuttons & axes and by running it opens a GUI window to observe the simulation results.

By selecting appropriate input images of CT and MRI, the DWT of CT, MRI and fused images were generated and the figures are shown below.

Fig.3 & Fig.4 are the CT and MRI images. Fig. 5 and Fig.6 are the DWT of CT & MRI images respectively. Finally fig.7 is the fused image, which consists of more information than CT & MRI images.

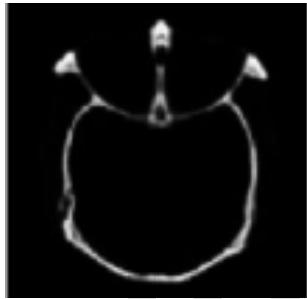


Fig 3: CT image of brain

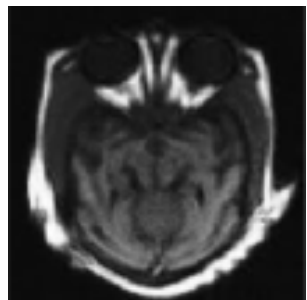


Fig 4: MRI image of brain.

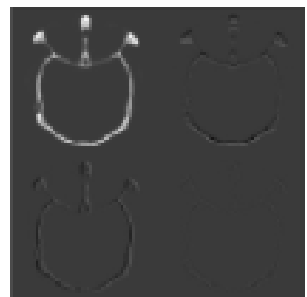


Fig 5: DWT of CT image

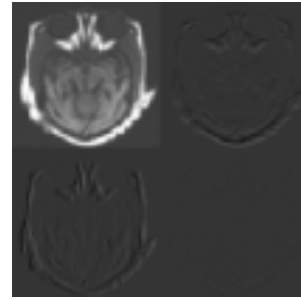


Fig 6: DWT of MRI image

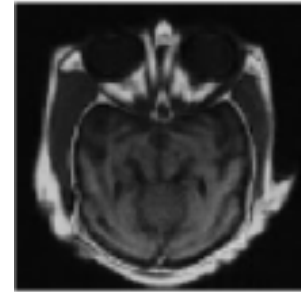


Fig 7: Fused Image

#### 4.2 Implementation Results

The implementation process can be done with the use of XPS, VB softwares & FPGA hardware. After converting the input images into header files and then the DWT, IDWT and fusion codes added in the source files.

By selecting Hardware & Software architectures and adding source, header files. Then generate netlists and bit streams for the specified file, then convert it into bit-streams and download into FPGA, the kit is shown as in fig. 8 and run it by using Visual Basic (VB). To implement this paper Spartan-3 EDK (3s200tq144-4) families FPGA, this consists of suitable features for this paper.

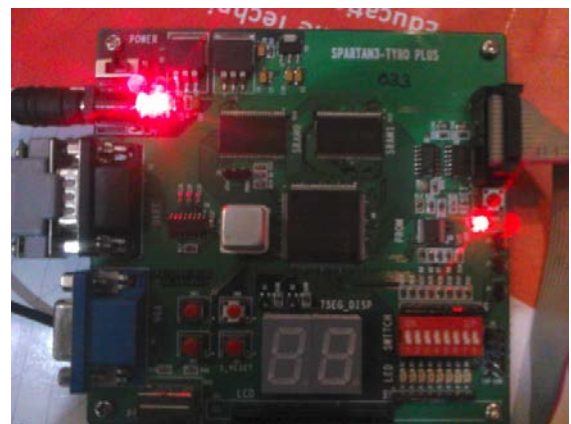


Fig 8: FPGA kit after downloading bitstreams

Then the output is displayed in VB window for the respective images. Fig. 9 and Fig. 10 are the implementation of CT image, MRI image. The DWT of CT, DWT of MRI are shown in Fig. 11 and 12 respectively.

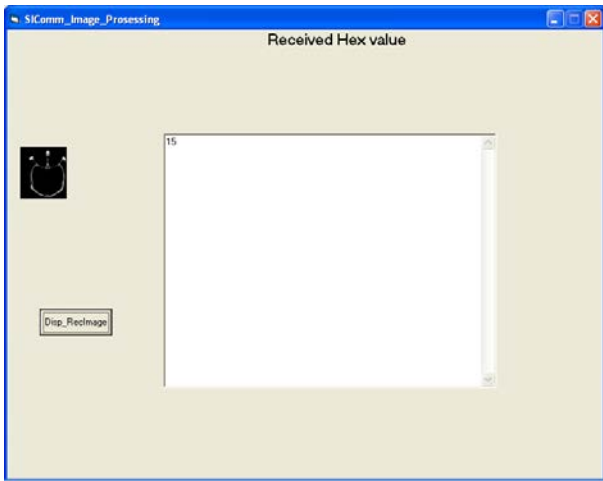


Fig 9: Implementation of Brain CT Image

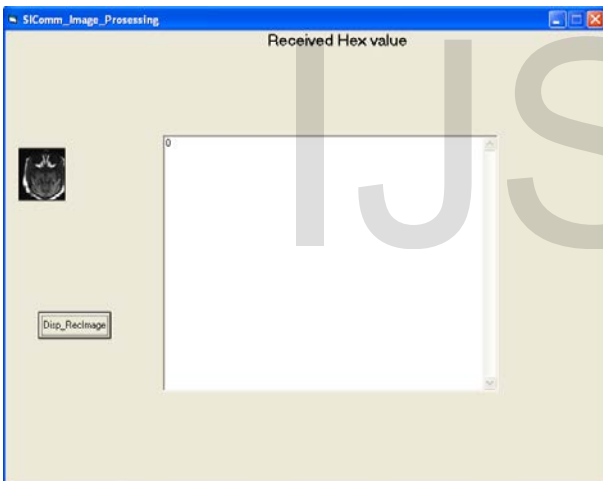


Fig 10: Implementation of Brain MRI Image

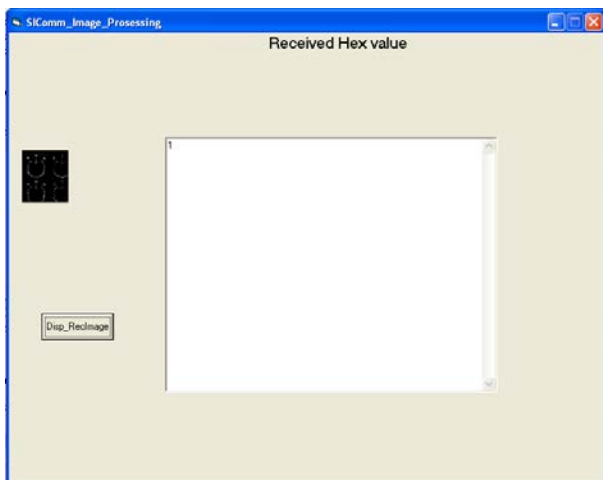


Fig 11: Implementation of Brain DWT-CT Image.

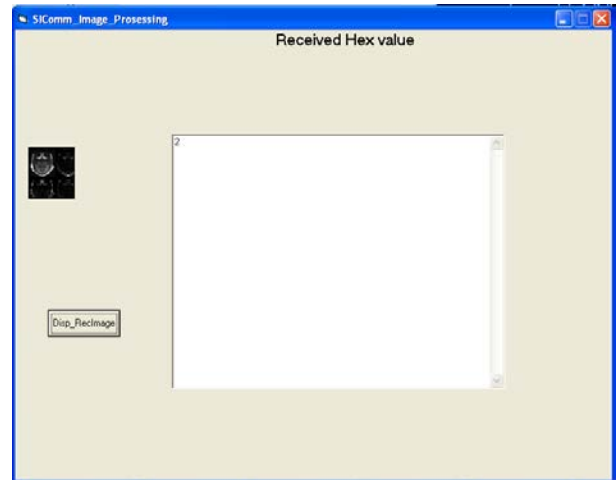


Fig 12: Implementation of Brain DWT-MRI Image.

The final fused image is shown in Fig. 13, which consists of more information than the CT and MRI images.

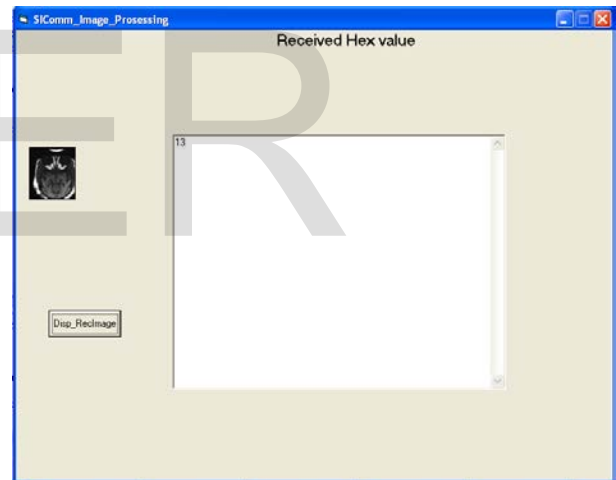


Fig 13: Implementation of Brain Fused image.

## 5 CONCLUSION

In this paper the image fusion is done by applying DWT to the CT and MRI images and implemented it by using the FPGA hardware. Different fusion rules were tested, including mean rule, maximum rule, minimum rule and random rules. Here maximum rule gives better result. So, Maximum rule is selected.

The images used in this paper are gray-scale CT and MRI images. However, the images of other modalities (like PET, SPECT and X-ray etc.) with their true colour nature may also be fused and implemented using this method.

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