FPGA Implementation of Medical Image Fusion Using SPARTAN FPGA Image Processing Kit

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***Abstract*—Our work proposes an approach for combining two multimodality images [CT and MRI] with tumor cell, helps to define the anatomical and physiological differences from one dataset to another using Discrete Wavelet transform. Image fusion is the process that combines two or more image datasets resulting in a single image dataset. There are many fusion processes that can take place at different levels. The fused image contains both soft tissue information like Tumor and also hard tissues information like bones, helpful for doctors to calculate the area of tumor for surgical planning. In this paper, a hardware implementation of an image fusion system is proposed using FPGA. Implementation of these algorithms on a FPGA is having advantage of using large memory and embedded multipliers. Advances in FPGA technology with the development of sophisticated and efficient tools for modeling, simulation and synthesis have made FPGA a highly useful platform. 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. Then, to prove the improvement in diagnosis content in fused image, various parameters like mean, standard deviation, energy, entropy, homogeneity, RMS, etc. are calculated and compared.**

***Index Terms*— Multimodality Images, Image Fusion, Discrete Wavelet Transform, FPGA, MATLAB, XPS.**

I. INTRODUCTION

Image fusion is an extensively discussed topic for improving the information content of images. The main objective of image fusion algorithm is to combine information from multiple images of a scene. The result of image fusion is a new image which is more feasible for human and machine perception for further image processing operations such as segmentation, feature extraction and object recognition. Image fusion is very important subject related to different areas such as object detection, image processing, robotics, and medical imaging. The indentations are to maximize resolution, decrease artifacts and improve parameters in the final fused image. To accelerate the entire operations, it is proposed to offload the image processing algorithms to a hardware platform thereby the performance can be improved. FPGAs provide an excellent platform in implementing real time image processing applications, since inherent parallelism of the architecture can be exploited explicitly. This paper explores the possibility of using the discrete wavelet transform approach in medical image fusion.

Image fusion can take place on pixel-level, feature-level, and decision level.

1) Pixel-level image fusion is the combination of raw data from different multiple source/input images into a single image.
2) Feature -level fusion technique needed the extraction of different features from the source/input data before the features are combined together.
3) Decision-level fusion fused the results from multiple algorithms to give a final fused output.

In this paper, Pixel level image fusion is performed. This fusion has various methods such as weighted average, Principal Component Analysis (PCA), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Stationary Wavelet Transform (SWT). The DWT method is important in an image fusion technique for its excellent feature & time frequency analysis. Wavelet transform fusion is defined as considering the wavelet transforms of two registered input images together with the fusion rule. The fused image is reconstructed by taking IDWT.

II. LITERATURE SURVEY

[1] "FPGA Based Medical Image Fusion on Spartan Kit for Lung Disease Detection", International Journal for Scientific Research & Development, 2020 by Prajakta Ambrale, Nikita Mahajan, Harshada Malusare, A.G. Gaikwad. In this disease detection project, CT scan and MRI scan pictures of the infected tissues inside lungs are gathered as an input. These pictures are dumped into the Spartan3 FPGA image processing kit which will diffuse both the pictures and give the output as an efficiently clear image about the size of an infected tissue through which a doctor can easily detect whether the infected tissue is malignant or benign.

[2] "VLSI Implementation of Image Fusion Using DWT- PCA Algorithm with Maximum Selection Rule", International Journal of Intelligent Engineering and Systems, 2019 by S. Borra, R. Panakala, and P. Kumar. In this work, DWT-PCA-IF architecture has been designed to perform the image fusion. The hybrid VLSI architecture provided better fused image compared to previous works

[3] "Implementation of Medical Image Fusion Using DWT Process on FPGA", International Journal of Computer Applications Technology and Research Volume 2– Issue 6, 676 - 679, 2013, ISSN: 2319–8656 by D. Khasim Hussain, C. Laxmikanth Reddy, V. Ashok Kumar. This paper presented a method for fusing two dimensional multi-resolution images using Discrete Wavelet Transform on SPARTAN FPGA Image processing kit.

[4] "The Application of Wavelet Transform to Multimodality Medical Image Fusion", IEEE Int. Conf. on Networking, Sensing and Control (ICNSC '06), Florida, pp 270-274 by Anna Wang, Haijing Sun, and Yueyang Guan. This work covers the selection of wavelet function, the use of wavelet based fusion algorithms on medical image fusion of CT and MRI, and the fusion image quality evaluation.

[5] "Multispectral image fusion for improved RGB representation based on perceptual attributes," Int. J. Remote Sens., vol. 26, no. 15, pp. 3241–3254, Aug. 2005 by V. Tsagaris and V. Anastassopoulos. A pixel-level fusion technique for RGB representation of multispectral images is proposed. The technique results in highly correlated RGB components, a fact which occurs in natural color images and is strictly related to the color perception attributes of the human eye.

[6] "A simple and efficient image fusion algorithm based on standard deviation in wavelet domain" , 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET) by Nirmala Paramanandham and Kishore Rajendiran,. A simple image fusion framework is developed based on the standard deviation, where consistency verification is used as a selection criterion in approximation band and maximum fusion rule to the detailed bands.

[7] "R-FUSE: Robust Fast Fusion of Multiband Images Based on Solving a Sylvester Equation", IEEE Signal Processing Letters (Volume: 23, Issue: 11, Nov. 2016) by Qi Wei, Nicolas Dobigeon, Jean-Yves Tourneret, Jose Bioucas-Dias and Simon Godsill. This paper proposes a robust fast multiband image fusion method to merge a high-spatial low spectral resolution image and a low-spatial high spectral resolution image.

[8] "Image Fusion with Guided Filtering", IEEE Transactions on Image Processing, 22(7), 2864-2875, by Shutao Li, Xudong Kang, Jianwen Hu. The proposed method is based on a two-scale decomposition of an image into a base layer containing large scale variations in intensity, and a detail layer capturing small scale details.

[9]"Image Fusion Based on Wavelet Transform", International Journal of Engineering Research,2014, by Jadhav and Souparnika. Complex Wavelet based fusion techniques have been used in combining perceptually important features. A novel image fusion technique based on dual-tree complex wavelet transform is presented in this paper.

III. PROPOSED METHOD

A. Description: The two images are fused together using Discrete Wavelet Transform (DWT) technique. The block diagram of the fusion system below consists of images, DWT technique, Spartan FPGA kit and fused image block.

B. Input multi-modality medical images: 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. So, CT and MRI images are taken as input images for this project.

For the image fusion, two images preferably of the same size are taken.

C. Discrete Wavelet Transform: The Wavelet Transform is a multi-decomposition of an image in biorthogonal basis and results in a non-redundant image representation. This basis is called as wavelets i.e., they are the functions generated from one single function called as a mother wavelet. DWT-IDWT based image fusion technique which consist of two input images, wavelet coefficient and fusion decision map, and the fusion block. The two input images image1 and image2 are taken as inputs. The wavelet transforms decompose the image into LL, LH, HL, HH frequency bands.

D. Hardware Used:

1 Spartan-6 FPGA Image Processing Kit: Image processing algorithms are conventionally implemented in DSP, ARM processors and some special purpose processors. However, all these implementation styles are limited by throughput which becomes very critical parameter for several image processing applications. The FPGA technologies offer basic digital blocks with flexible interconnections to achieve high speed digital hardware realization. In this project the Spartan-6 FPGA kit is used. Spartan-6 FPGAs are programmed by loading configuration data using JTAG cable into reprogrammable, static CMOS configuration latches (CCLs) that collectively control all functional elements and routing resources.

2 JTAG USB Programmer

3 Serial Cable

4 PC

E. Software used:

1 Xilinx ISE 10.1i or above which comes with Xilinx Platform Studio (XPS) and Xilinx SDK.

2 VB GUI to display output

3 MATLAB

IV. WORKING PROCEDURE

This project involved the implementation of the medical image fusion using FPGA. This project is implemented in 6 steps.

STEP-1: Conversion of input medical images into header files in MATLAB

In the process of image fusion technique, a MATLAB GUI is built for conversion of images into header files. First the input image 1 i.e., CT scan image is pre-processed by MATLAB and converted into .h file. Then the input image 2 i.e., MRI scan image is pre-processed by MATLAB and converted into .h file.

STEP-2: Selection of Hardware Configuration

Xilinx Platform Studio is used for configuring the hardware. Select the Hardware configuration like processor, IO peripherals etc. The HDL codes are generated automatically for each specified hardware selection and then convert it into bit streams.

STEP-3: Selection of Software Configuration

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-4: Convert all the codes into bit streams and dump the code onto FPGA board using JTAG cable

Compile the code and convert into executable linker file. Then download hardware and software architecture bit streams into FPGA and run it.

STEP-5: View the output on Visual Basic GUI

The image output can't be shown in FPGA. For this purpose, Visual Basic GUI is built to observe the fused image output.

STEP-6: Calculation of parameters to see the improvement in content of fused image

The image contains several features which serve as characteristics that capture properties of the image. Texture feature is defined by using Gray Level Co-occurrence matrix (GLCM). From this the parameters calculated and compared are Contrast, Correlation, Energy and Homogeneity. Then the morphological feature extraction is done to calculate the parameters like Mean, Standard deviation, RMS and Entropy.

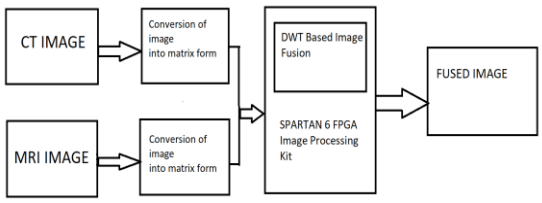


Figure.1. Block diagram of Implementation of Image Fusion Technique using FPGA

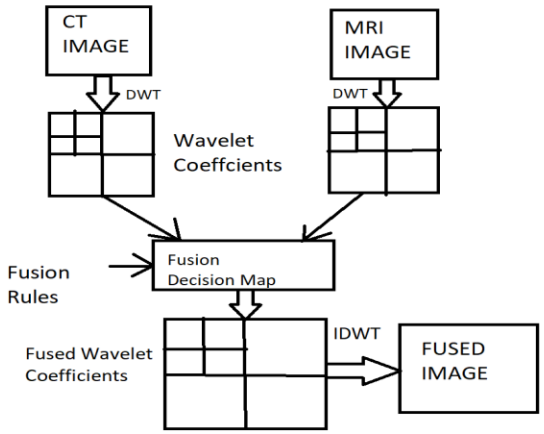


Figure.2. Image Fusion process using DWT

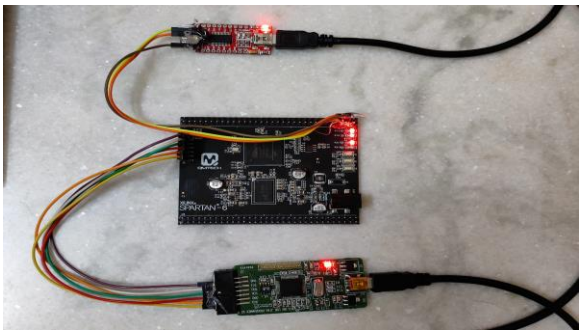


Figure.3. Hardware used

V. RESULTS

In the proposed algorithm, we mainly focused 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 and programming the GUI components.

The implementation process is done with the use of XPS, VB software & FPGA hardware. Then the output is displayed in VB window for the respective images. Fig. 5 and Fig. 6 are the implementation of CT image, MRI image. The DWT of CT, DWT of MRI are shown in Fig. 7 and 8 respectively.

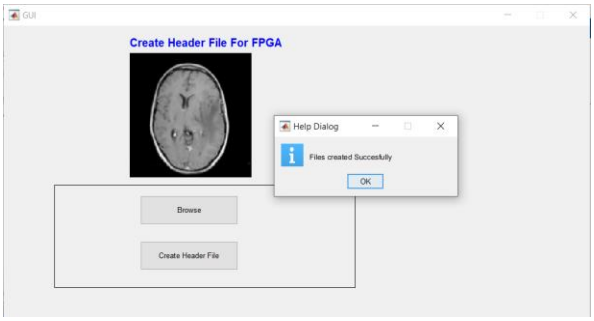


Figure.4. MATLAB GUI

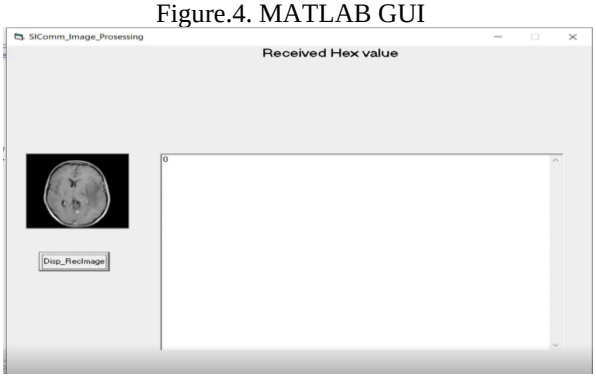


Figure.5. CT Image

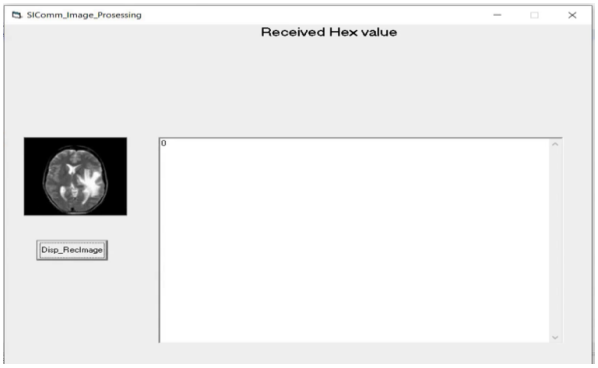


Figure 6 MRI Image

DWT is applied to the input image, which is decomposed into four sub image. These sub images are named as sub bands.

The LL sub band is the coarse level sub image, HH, LH, and HL are the diagonal, vertical and horizontal components of the image respectively.

Figure 7 DWT of CT Image

Figure 8. DWT of MRI Image

Once we arrive at our discrete wavelet coefficients, we need a way to reconstruct them back into the original signal (or a modified original signal if we played around with the coefficients). In order to do this, we utilize the process known as the inverse discrete wavelet transform.

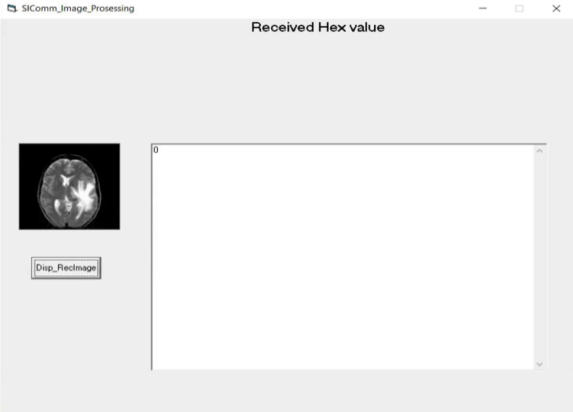
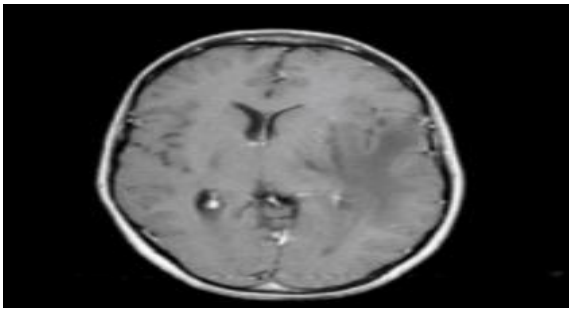


Figure 9. Fused Output Image

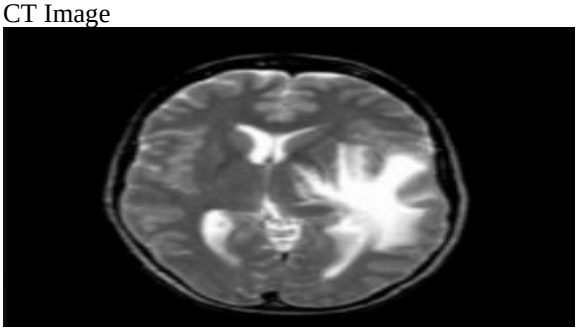
PARAMETERS CALCULATED AND COMPARED

Parameters	CT Image	MRI Image	Fused Output
Contrast	0.3011	0.1758	0.3352
Correlation	0.9379	0.9599	0.9751
Energy	0.3505	0.3727	0.3286
Homogeneity	0.9363	0.9311	0.9173
Entropy	4.4230	4.4569	4.8981
Mean	47.9548	55.774	61.4565
Standard Deviation	66.5274	70.245	72.9523
RMS	61.6231	70.369	74.205

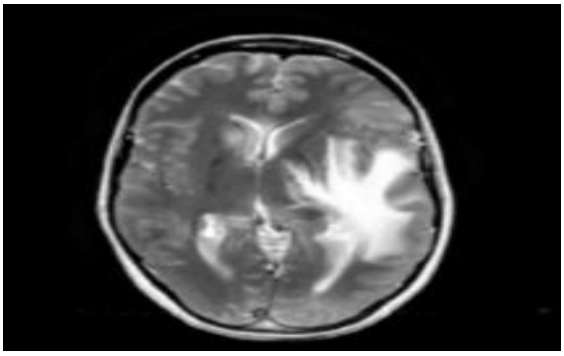
1 The contrast of fused image is 11.32% greater than CT image and 90.67% greater than MRI image.
2 The correlation of fused image is 3.96% greater than CT image and 1.58% greater than MRI image.
3 The energy of fused image is 6.24% lesser than CT image and 11.84% lesser than MRI image.
4 The homogeneity of fused image is 2.02% lesser than CT image and 1.48% lesser than MRI image.
5 The entropy of fused image is 10.74% greater than CT image and 9.89% greater than MRI image.
6 The mean of fused image is 28.16% greater than CT image and 10.18% greater than MRI image.
7 The standard deviation of fused image is 9.65% greater than CT image and 3.88% greater than MRI image.
8 The RMS of fused image is 20.41% greater than CT image and 5.45% greater than MRI image.



CT Image



MRI image



Fused Output

VI. CONCLUSION

The resultant image is more reliable, clear and more accurate. Image fusion is giving a new image that retains the most desirable information and characteristics of each input image. The fused image contains better information content for the diagnosis than any one of the individual input images alone. The fused image is generated to improve the image content and to make it better for the user to detect, recognize and identify diseases.

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