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Implementation of Realtime Image Fusion for Biomedical Applications Using ICA And Discrete Wavelet Transform

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ABSTRACT- Image fusion is an extensively used technique in various areas like computer visualization, enhanced diagnostic imaging, radio therapy, automatic object recognition, image analysis, and remote sensing. The main aim of image fusion is to combine several input images into one image containing more information than the individual images. This type of image fusion results in a new image that is easier for computers and humans to see, making it possible for additional image processing operations like object detection, segmentation, and feature extraction. This paper examines the potential application of customized wavelet transform for image fusion. This paper is implemented for biomedical applications by using wavelet-based pixel-level image fusion technique and Independent Component Analysis (ICA) for de-noising. For realization of this, Initially, MRI and CT pictures are extracted using the 2D discrete wavelet transform and then ICA is used to obtain ICA bases and fused on the sub band pictures. The suggested methodology is implemented in FPGA Spartan and Virtex devices since FPGA provides a good platform for image processing in real-time and finally the performance has been compared with the existing methodologies.

Keywords: Image fusion, Bio medical, independent component analysis, discrete wavelet Transform, Field Programmable Gate Array.

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1. INTRODUCTION

Fusion of images is a process of integrating data from multiple images, such as CT and MRI, and combining them into a single image. This converted solitary image is supplementary tightfitting and detailed than slightly further single source image with all obligatory information. It serves as a means of both minimizing data and producing more comprehensive images that can be appreciated by humans and machines. The process of fusing multiple sensors into one image involves merging permanent details from each sensor individually. As a result, the resulting image will have a greater degree of information than the input images. Image fusion is a process in digital image processing entails the amalgamation of multiple images to produce a singular image that encapsulates the most significant information from each source images. This can be done for various purposes, such as enhancing image clarity, improving the visualization of details, or extracting useful information from different image sources. Image fusion techniques are commonly used in fields like remote sensing, medical imaging, and computer vision to make better use of available visual data. There are different techniques and methods for image fusions some are, pixel-level fusion, feature-level fusion, transform domain fusion, Multiscale fusion Image synthesis can be applied to various scenarios, including remote Sensing, medical imaging surveillance, computer vision, astronomy.

Researchers continue to develop and refine image fusion techniques to achieve better results in various applications many research has been carried out earlier in area of image fusion According to [1] wavelet models with wavelets graphic (WG) models outperform Laplacian pyramid-based image fusion well. This superiority is attributed to the wavelet transforms compactness, directional selectivity, and orthogonality. In [2], author focused on feature extraction in medical MRI images. They conducted a comparison between the Sobel and Canny edge detection method. To assess their effectiveness a single slice of MRI image tested with both method of edge detection method in [3], it was stated that medical image fusion is a specialized technique wherein various medical images originating from different wavelength ranges and employing different imaging mechanisms are amalgamated into a unified scene. The resultant fused image exhibits enhanced reliability, reduced fuzziness, improved comprehensibility, and is better suited for humanoid pictorial acuity and also for processor created errands such as detection, classification, recognition, understanding, and other processing. In [4], the focus was on image fusion for medical diagnosis using the wavelet transmute. Originally derived from mallet, wavelet-based multiresolution analysis is based on the concept of wavelet-based resolution. Signal processing uses the wavelet transform to identify local features, one of its mathematical tools. It can also decompose two-dimensional signals, like grayscale images, into various tenacity echelons for multiple determination investigation. The wavelet renovate has found widespread submission in miscellaneous spheres, plus surface investigation, information determination, feature appreciation, and image synthesis. [5-7], The paper is likely focused on the application of Field-Programmable Gate Arrays (FPGAs) for medical image fusion, particularly for the purpose of detecting heart diseases. FPGAs are versatile hardware devices used for various computational tasks, including image processing. In this context, the authors may discuss how FPGAs can be used to perform medical image fusion. X-rays, CT scans, or MRI scans can be combined to provide more accurate diagnostic information through image fusion and provide more comprehensive insights for medical professionals. The mention of a Spartan Kit" likely refers to the use of a development kit or hardware platform that includes Xilinx Spartan FPGAs. In [8], the paper seems to concentrate on the Very Large-Scale Integration (VLSI) implementation of an image fusion algorithm, particularly utilizing the Principal Component Analysis with DWT (DWT PCA) algorithm. It's probable that the paper delves into the DWTPCA algorithm as the chosen method for image fusion. Both the Distinct Wavelet Transform (DWT) and Primary Component Analysis (PCA) are commonly employed in image processing and fusion endeavours. [9], Wavelet Transform is a mathematical and signal processing technique used in image processing for analysing and transforming images into different frequency components. It is particularly useful for feature extraction, compression, and fusion. Image fusion in the medical context aims to enhance diagnostic capabilities by combining complementary information from multiple imaging modalities. This can lead to improved visualization, increased accuracy in diagnosis, and better monitoring of medical conditions. ICA can be used for multi signal decomposition without losing any data, this has high applications in the field of image and signal processing areas [10, 11]. ICA can be integrated with adaptive filters which used LMS (Least mean square) error co-efficient updating for low hardware resource utilization. Based on the observations on previous research, in biomedical imaging, multiple imaging modalities (e.g., MRI, CT, PET) are often used to provide comprehensive information about the patient's anatomy and physiology. However, each modality has its own strengths and limitations, capturing different aspects of the subject. For instance, MRI provides excellent soft tissue contrast, while CT offers high-resolution images of bone structures. The challenge lies in combining these different images into a single, more informative image that retains the critical diagnostic information from each modality. Traditional image fusion techniques may struggle with issues such as noise, artifacts, loss of important features [12, 13], and computational inefficiency, particularly when real-time processing is required. In this research the ICA is integrated with DWT and this method effectively captures and preserves crucial diagnostic information from multiple imaging modalities, resulting in fused images with improved detail, contrast, and clarity. This enhances the quality and informativeness of biomedical images, aiding in more accurate and reliable diagnoses.

2. IMAGE SYNTHESIS

Image synthesis proposed methodology is shown in *figure 1* in this method image of CT and MRI are written in MATLAB the image need to be loaded and converted to gray scale further it is converted to binary code using MATLAB tool. These binary values are later converted to text file which can be given as input to FPGA.

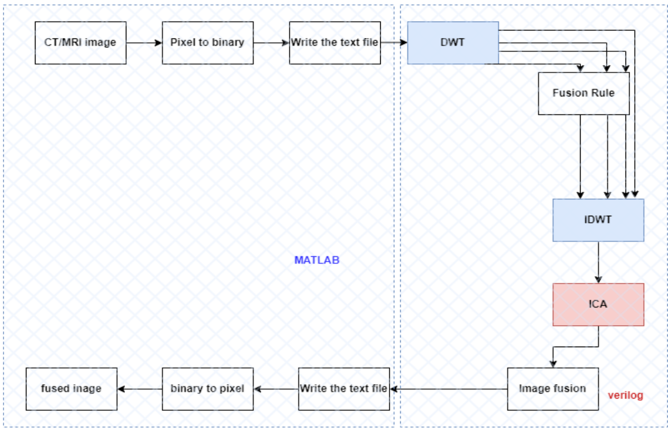

Figure 1. Block diagram of image synthesis

The binary pixels are processed by DWT which converts into frequency components of different bands. These frequency components are given to IDWT followed by ICA which can used for fusing. This DWT/IDWT and ICA are written in Verilog which can be used to implement in hardware. Later for visualisation these images are again converted to MATLAB.

2.1 Image pre-processing

Before processing the image fusion, the MRI and CT images has to be pre-processed. The steps follow is given below *figure 2*. Once the pre-processing steps are done the images are read into MATLAB and each pixel are converted into binary values which can be analysed by the computers. later these binary values are stored as text file.

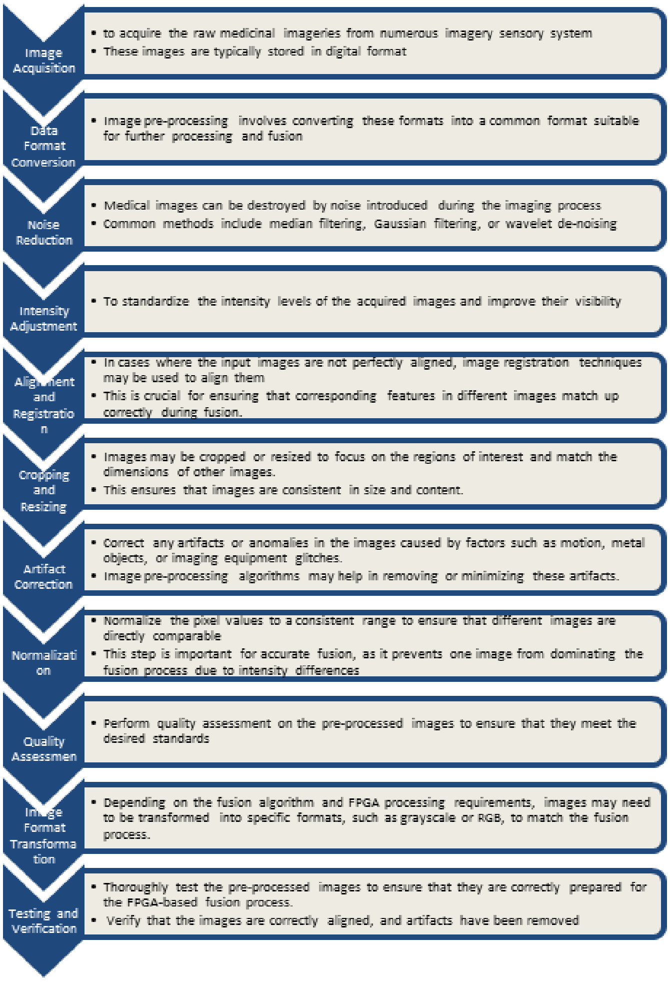

Figure 2. Pre-processing steps for image fusion

There are quatern main gears to the participation images in *figure 3*, each capable of containing 32 bits of information. 2D architecture of DWT is shown in below *figure 8* bits even and odd bits are given as even_in [7:0] and odd_in [7:0] these signals are controlled by the control inputs of clk and rst. In parallel basis this even and odd inputs are extracted. After processing the final output are extracted as dc_out and sc_out.

Discrete wavelet transform (DWT) process is carried out for the text file and low and high frequency components are separated in the DWT operation. DWT will convert time domain into frequency domain. Structure of DWT is shown in *figure 4*. In image dispensation using the 2D DWT, every row and column of an image is endangered to wavelet putrefaction. If the contribution image has scopes in the range 2^k × 2^k picture element at phase L, after fragmentation at period L+1, its size will convert to 2^(k+1) × 2^(k+1) picture element. This decomposition process results in the image being divided into four smaller sub-images, referred to as "sub-bands". These sub-bands include the coarse level sub-image represented by the A1(approximation or low frequency) sub-band, and the diagonal (D1 or high occurrence), vertical (V1 or high incidence), and horizontal (H1 or high frequency) mechanisms of the twin. Every apparatus characterizes diverse frequency gratified of the image.

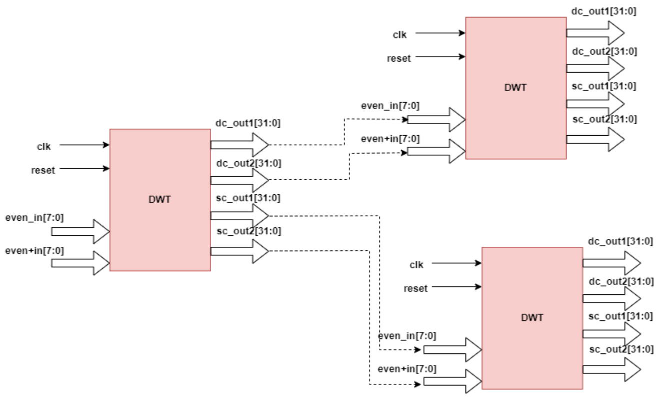

Figure 3: DWT architecture

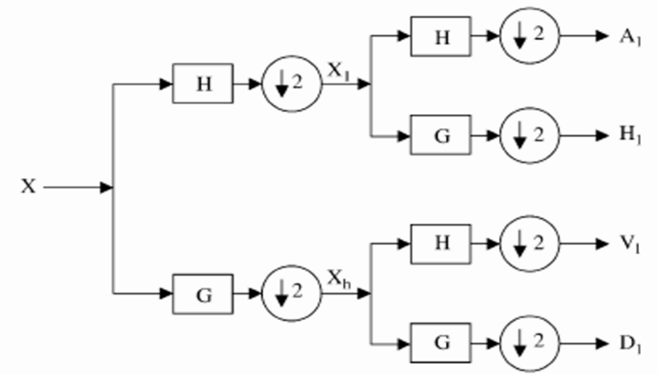

Figure 4. Discrete wavelet transmutes

Schematic view of the image fusion is shown in the below *figure 5* where two images are combined using DWT with 4 different frequency level LOWER-LOWER, LOWER-HIGHER, HIGHER- LOWER and HIGHER- HIGHER.

3. FUSION ALGORITHM

There are many algorithms are used to fusion the images in this some algorithms are computationally intensive and may require optimization for hardware acceleration. Before selecting the appropriate algorithms, the following points to be considered. Accuracy and Information Preservation: Consider the ability of the algorithm to preserve important information from the input images.

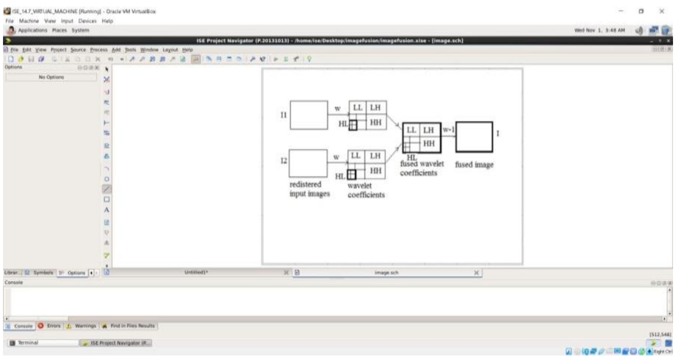

Figure 5. Schematic view of respective DWT

The selected algorithm should retain critical details and features, as medical image fusion is often used for diagnostic

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purposes. *Robustness to Registration Errors:* In cases where input images may not be perfectly registered, consider algorithms that can handle misalignment and registration errors. Robust fusion techniques can compensate for misalignments during the fusion process. *Adaptability:* Some fusion algorithms can adapt to the specific characteristics of the input images and the region of interest. Adaptive algorithms can optimize the fusion process based on local image content. *Complexity and Resource Utilization:* Assess the complexity of the algorithm and its resource requirements.

Ensure that the selected algorithm can be efficiently implemented on the Spartan FPGA, considering available resources such as logic cells, memory, and processing units. Ensure that the selected fusion algorithm can be effectively translated into VHDL or Verilog for FPGA implementation. Compatibility with FPGA development tools is essential. Iterative Development: Be prepared for an iterative development process. In this proposed methodology DWT is integrated as fusion algorithm since ICA can be used to extract independent component better compared to other existing architecture. And it has shown better results in signal processing applications.

4. INDEPENDENT COMPONENT ANALYSIS

In the research discussed, the selection of the fusion algorithm plays a crucial role in image fusion applications. Independent Component Analysis (ICA) has been chosen for this purpose since ICA excels at extracting underlying independent sources, providing a more comprehensive decomposition of the image data. This is particularly beneficial in biomedical applications where different imaging modalities provide complementary information that needs to be effectively combined. In this approach, ICA is applied independently to each set of sub-images in order to extract a few independent components (ICs). Subsequently, an analysis is conducted on these collected ICs to eliminate any noise-related components. By reconstructing the ICs associated with the uncorrupted images, noise reduction in the sub-images is achieved.

ICA is a numerical calculational prototypical that fluctuates from Principal Component Analysis (PCA) in that it not only de-correlates participation indications but too declines high directive arithmetic associations. The accomplishment of applying the ICA approach to tasks such as edge detection in natural photos with woodland scenes has been demonstrated. ICA functions as an implementation built on higher directive information, interpreting the spectral characteristics of signals through linear transformations applied to multidimensional data. It enables the computation of concealed influences fundamental parallel indications, measurements, or time series sets.

An unidentified mixing system, the data variables are regarded as combinations of latent variables, either linearly or nonlinearly. These latent variables, also termed autonomous mechanisms of the pragmatic statistics, are presumed to be non-Gaussian and independent from each other. Independent Component Analysis (ICA) has the capability to distinguish these unique components, also known as sources or factors, from the observed data.

The theory of ICA has significantly advanced in various scientific domains having numerous applications. In recent times, ICA has found extensive applications in fields such as image compression, biological signal processing, adaptive speech signal processing [10],[11].

The ICA mixing model can be expressed using vector-matrix notations as follows:

$$X=AS=\sum_{i=1}^{n} aisi \quad (1)$$

where A - unidentified fraternization matrix, S= (s1, s2… sn) are the autonomous mechanisms, and X= (x1, x2,...,xn) is the remark. The objective is towards positioning the unidentified matrix W=A-1 such that a statistical independence criterion may be optimised to estimate the sources from the vector x. Several methods, including FastICA and Infomax, have been presented in recent years for the separation of independent components. We employ the FastICA method in this paper. This algorithm achieves the separation aim by maximising neg entropy and has a rapid convergence speed.

5. FPGA IMPLEMENTATION

The proposed FPGA implementation for medical image fusion used carried out using Spartan and virtex FPGA devices. An integrated circuit known as an FPGA is made up of numerous identical logic cells, or standard components. Every logic cell has the ability to independently adopt any of a small number of personas. Programmable switches and a network of wires link the individual cells. By defining the basic logical functionalities for each cell and shutting switches in the assembly matrix one by one. a user's design is put into practice. FPGAs are turning into an essential component of all system designs. Numerous suppliers provide a wide range of structures and procedures. The FPGA is used in the system design to execute the synthesis processes on hardware. The contribution imageries are imperilled to wavelet renovates, synthesis, and reverse wavelet transforms. The construction strategy for these practices has realized on a Spartan-3 Xilinx board, and work on designing the picture fusion modules is still ongoing. This proposed method used Spartan FPGA device due to the compatibility. The FPGA board is connected to the system using JTAG cable. Now the converted text file is dumped into the FPGA and the analysis are done using Xilinx software. In the described process, image pixels are applied into Xilinx models either as a multidimensional image signal or as separate R|G|B color signals in vector form, utilizing the Xilinx fixed-point format. These models are then simulated within the MATLAB environment with appropriate simulation time and mode, and the results are visualized using a video viewer. Once the desired outcomes are achieved, the Xilinx System Generator is configured for the SPARTAN and Virtex FPGA boards, with SPARTAN being utilized in this scenario.

The SPARTAN board is designed to enable the development and assessment of All Programmable System on Chip (SoC) designs, offering a platform ideal for swift prototyping and

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proof-of-concept validation. It incorporates essential features and compatibility with Digilent Pmod™ extension headers, alongside standard system design components. Equipped with the SPARTAN 4 FPGA, it provides embedded computing functionalities supported by architectural technologies.

Clock and I/O planning are performed, and the model is subjected to JTAG hardware co-simulation. Parameters in the System Generator are configured and generated, resulting in the generation of a netlist and a draft of the model in Verilog HDL, accessible through Xilinx Vivado. The module undergoes behavioral syntax checking, synthesis, and implementation on the FPGA. The System Generator also provides features for generating User Constraints Files (UCF), test vectors, and test benches for architecture testing.

6. RESULT AND DISCUSSION

The presentation of the image synthesis is supported Xilinx. The contribution imageries taken from CT and MRI as revealed in *figure 6*. The hardware Spartan is connected with the computer by using JTAG cable in *figure 7*. Since the performance of image fusion is implemented in FPGA the comparison of exiting methods with the proposed is tabulated in *table 1*. It presents the FPGA performance metrics for Virtex 4 and Virtex 5 devices. These metrics include LUT (Look-Up Table), flip-flop count, number of slices, and operating frequency.

The values in the table demonstrate that the DWT-PCA-IF architecture outperforms other architectures in terms of these FPGA performance parameters. Additionally, the schematic diagram of the DWT (Discrete Wavelet Transform) and the hardware connections are illustrated in *figure 8*.

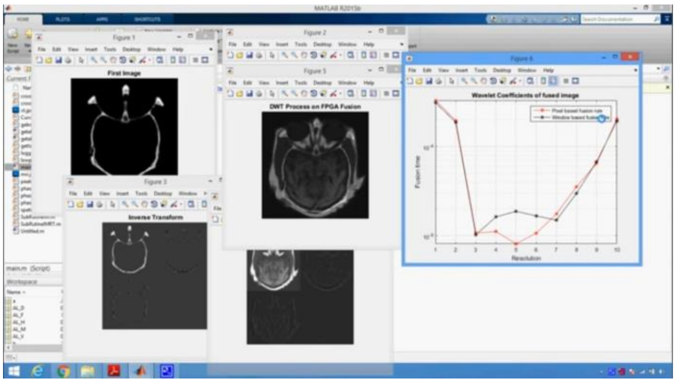

Figure 6. MATLAB MRI image

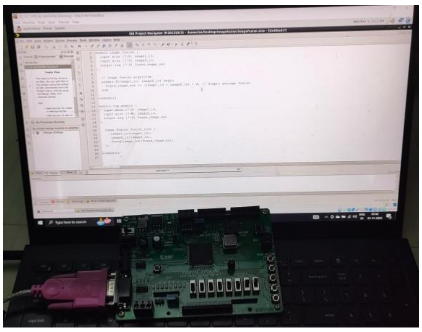

Figure 7. Spartan kit connected with PC using JTAG

Table 1: Performance comparison with existing methods

Device used	method	No of LUT	Number of FF	Number of Slices	Frequency
Virtex 4	[16]	4038	4852	2857	250.3
	[17]	4002	4657	2634	289.64
	[18]	3541	4214	2011	314.21
	[19]	3014	3987	1968	355.14
	DWT-ICA	2961	3475	1621	385.17
Virtex 5	[16]	3014	4125	1964	185.41
	[17]	3014	4032	1847	193.21
	[18]	2987	3987	1752	255.14
	[19]	2741	3789	1648	287.96
	DWT-ICA	2521	3298	1541	302.21

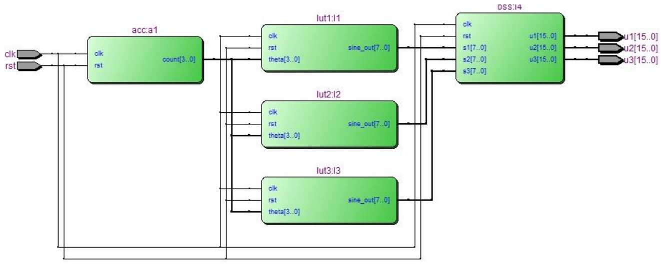

Figure 8. Schematic view of DWT

7. CONCLUSION

The projected construction has been accurately considered to enhance utilization of hardware effectively. The research endeavour, the Discrete Wavelet Transform-Independent Component Analysis architecture was developed for image fusion applications. Medical images such as MRI and CT scans were employed in the synthesis progression towards extract richer evidence. The concerts are realized in Spartan and Virtex FPGA devices. The hybrid VLSI architecture yielded superior fused images associated to preceding policies. The DWT-ICA construction was realized and deployed on both Spartan and Virtex devices. This approach leverages the capabilities of these FPGA platforms to efficiently process and fuse medical image data, offering enhanced performance and accuracy in image fusion tasks.

Limitations:

- The fusion process may be sensitive to noise in input images, leading to degraded fused images. This can particularly affect the quality of medical images where noise is common.
- Variations in image quality across different imaging modalities or due to equipment differences can impact the fusion results, leading to inconsistencies or artifacts in the fused images.
- In generalizing across different types of biomedical images or imaging modalities, as the effectiveness of the fusion process can vary.

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