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Performance of Wavelet based Medical Image Fusion on FPGA using High Level Language C

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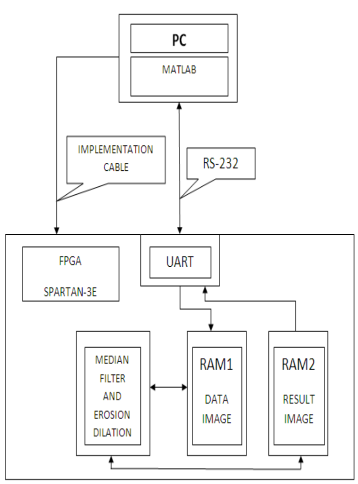
K. Umapathy[a]*, V. Balaji[b], V. Duraisamy[c], S. S. Saravanakumar[d]

[a]Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya Department of Electronics and Communication Engineering, Enathur, Kancheepuram, Tamilnadu, India
[b]Prince Shri Venkateshwara Padmavathy Engineering College Department of Electronics and Communication Engineering, Ponmar, Chennai, Tamilnadu, India
[c]Principal, Maharaja Institute of Technology, Coimbatore, Tamilnadu, India
[d]Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya Department of Electronics and Instrumentation Engineering, Enathur, Kancheepuram, Tamilnadu, India

*Corresponding authors
kumapathy@gmail.com

Graphical abstract



Abstract

In this paper presents the implementation of wavelet based medical image fusion on FPGA is performed using high level language C. The high- level instruction set of the image processor is based on the operation of image algebra like convolution, additive max-min, and multiplicative max-min. The above parameters are used to increase the speed. The FPGA based microprocessor is used to accelerate the extraction of texture features and high level C programming language is used for hardware design. This proposed hardware architecture reduces the hardware utilizations and best suitable for low power applications. The paper describes the programming interface of the user and outlines the approach for generating FPGA architectures dynamically for the image co-processor. It also presents sample implementation results (speed, area) for different neighborhood operations.

Keywords: Morphology, Matlab, FPGAs, image processing

1.0 INTRODUCTION

Image fusion is the process of combining relevant information from two or more images into a single image. Then the resultant image has more information than input images. Image fusion has become a topic of great interest to the engineers working in different fields. It is being used for medical applications to get a better image. It is also being used in automotive industries to enhance the vision of road, to observe a better image during a rainy weather. Due to the increasing demand, high-resolution images are available along with sensor technology development. The image fusion is still important and easy method to interpret the image data and obtain a more suitable image for a variety of applications, such as visual interpretation, satellite, digital classification & war-field. The main objective of medical imaging is to obtain a high resolution image with complete for the sake of diagnosis. MRI and CT imaging are of main concern for diagnostic purposes. 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. Wavelet transform fusion is defined as considering the wavelet transforms 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 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. A Spatial domain fusion is directly applied on the source images which is reduces 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. Using Inverse transformation on this decision map gives the fused image. The fused image includes all the details of the source images and reduces the spatial distortion.

Field Programmable Gate Arrays are reconfigurable devices. Hardware design techniques such as parallelism and pipelining techniques can be developed on a FPGA, which is not possible in dedicated DSP designs. Implementing image processing algorithms on reconfigurable hardware minimizes the time-to-market cost, enables rapid prototyping of complex algorithms and simplifies debugging and verification. Therefore, FPGAs are an ideal choice for implementation of real time image processing algorithms. FPGAs have traditionally been configured by hardware engineers using a Hardware Design Language (HDL). The two principal languages used are Verilog HDL (Verilog) and Very High Speed Integrated Circuits HDL (VHDL) which allows designers to design at various levels of abstraction.

2.0 RELATED WORKS

Over the years, multiple efforts have been made to develop new image fusion techniques. Additionally, efforts have been made to review and assess the image fusion qualities. However, there are still a large number of open issues that need to be resolved in this area. The image fusion system based on wavelet decomposition for unmanned airborne vehicles (UAVs) is probably the first investigation adaptive image fusion that makes use of dynamic reconfiguration to change the fusion algorithm as the UAV approaches an object of interest. Sims and Irvine presented an FPGA implementation using pyramid landed composition and subsequent fusion of dual video streams. This realization gives a design that can fuse dual video streams in gray scale video graphics array (VGA), with 30 frames/s in real time. Both hardware designs showed an improvement in speed performance compared to respective algorithms running on a typical PC, giving strong indications of the advantages of hardware against software implementation.

Following are the some image fusion technologies having its own advantages and disadvantages Fusion using Principle Component Analysis (PCA): The PCA image fusion method simply uses the pixel values of all source images at each pixel location, and adding a weight factor to each pixel value, and takes an average of the weighted pixel values to produce the result for the fused image at the same pixel location. The optimal weighted factors are determined by the PCA technique.

3.0 IMAGE ALGORITHM

This section discusses the theory of most commonly used image processing algorithms like (1) Filtering, (2) Morphological operations.

3.1 Median Filtering

A median filter is a non-linear digital filter which is able to preserve sharp signal changes and is very effective in removing impulse noise (or salt and pepper noise). An impulse noise has a gray level with higher or lower value that is different from the neighborhood point.

Linear filters don't have ability to remove this type of noise without affecting the distinguishing characteristics of the signal. Median filters shown in Figure 1 have remarkable advantages over linear filters for this particular type of noise. Therefore median filter is very widely used in digital signal and image/video processing applications.

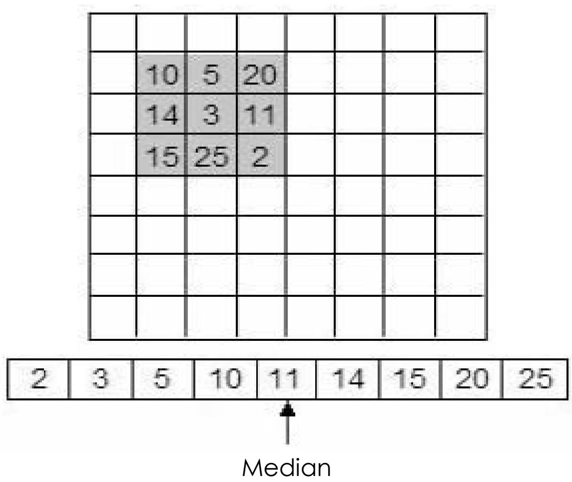


Figure 1 Median filter

4.0 PROPOSED ALGORITHM

Figure 2 shows the block diagram of implementation of proposed fusion algorithm. It consists of median or spatial filter, wavelet based edge detector, fusion block. The median filter serves to reduce blurring and aliasing produced by linear interpolation, the input pixels of input images are filtered by mean or spatial filter to enlarge the edges and remove the noise. Finally, the edge detected images are fused into a single image and then clipping circuit is used. It is followed by feature extraction circuit and minimum distance classifier circuit. Finally the fused image is classified as normal or abnormal image. The details of each part will be described in the following sections.

Step I: First the numbers are sorted vertically *i.e.* sort elements of each column in the ascending order.

Step II: Numbers are sorted horizontally *i.e.* sort elements of each row in the ascending order.

Step III: Sort the cross diagonal elements and pick up the middle element as the median element of the window. Minimum is the first and maximum is the last element in the window of the nine elements.

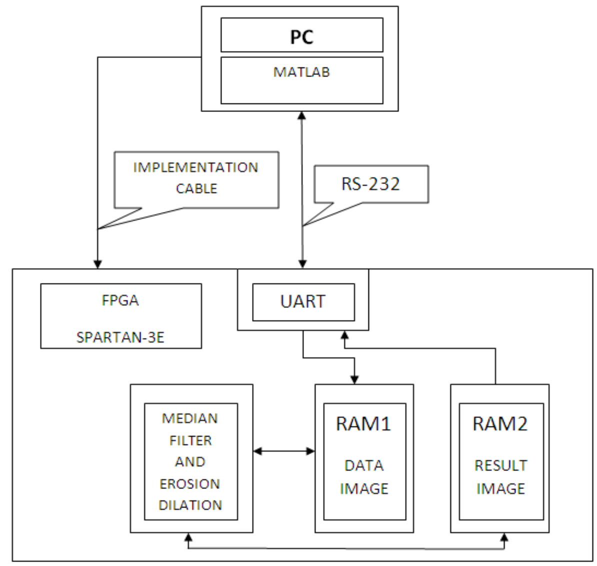


Figure 2 Block diagram of design implemented on FPGA

5.0 IMPLEMENTATION

The entire implementation of image acquisition, image processing and image retrieval is shown in block diagram of Figure 3. In order to reduce complexity of data transactions, RAM is implemented on FPGA. UART is implemented to felicitate data acquisition and communication between PC and FPGA board.

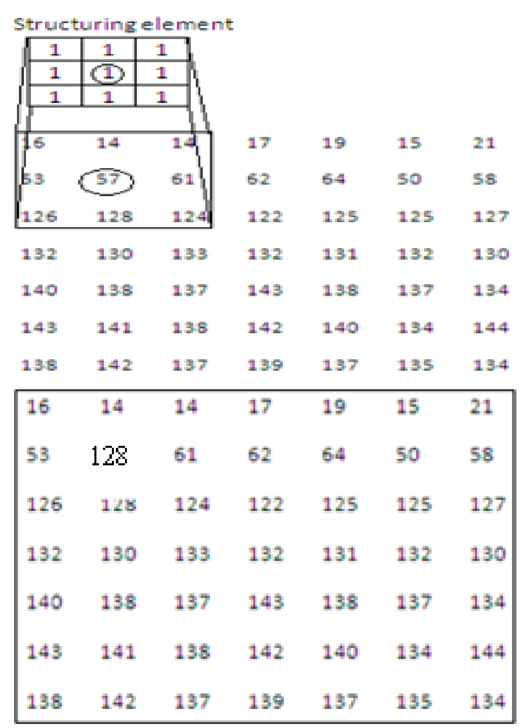


Figure 3 Block Schematic of Sort-3

6.0 RESULTS AND DISCUSSION

Our proposed fusion method is quantitatively evaluated and compared in terms of subjective testing, i.e., visual quality, where recommended parameters are used. For the quantitative testing of the fused images, we make use of the peak signal-to-noise ratio (PSNR) is a prime evaluation factor. From the results, it is observed that our proposed fusion methodology performs very well. The dataset used for our experimentation includes color PET scan images and normal brain MRI images. Both scan images have a resolution of 256×256 with 8-bit precision in the luminance channel. The metabolisms exposed by the PET scan are fused with the anatomical structures shown in the MRI scan in the final image which provides an enhanced spatial relationship. All the fused results are assessed by three clinicians who all have over five years working experience in the relevant field. The original image and the fused image are compared by the two quality metrics such as PSNR (Peak Signal to noise ratio), MMSE (Minimum mean square error), entropy and elapsed time.

The proposed fusion algorithm and its hardware architecture system is designed and tested on various version of Spartan-3E family device using Modelsim 6.1 and Xilinx 9.2i. This proposed scheme utilized 17 LUTs and 9 slices at a maximum frequency of 100MHz. The proposed work results shows that the system incorporated with its hardware architecture leads to lower power consumption in terms of slices, Look Up Tables and Flip Flops results shown in Figures 5 and 6.

The proposed fusion architecture is implemented in 90nm CMOS technology. The post layout results of the proposed fusion architecture are summarized in Table 1. Table 2 shows the performance comparison of the same architecture in quality metrics.

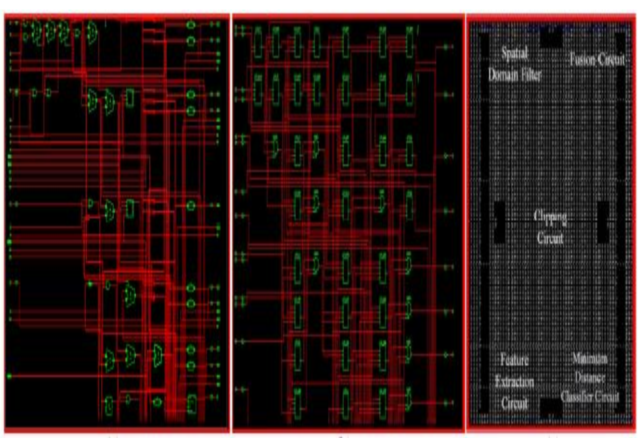


Figure 5 Simulation results for proposed system RTL schematic view chip layout

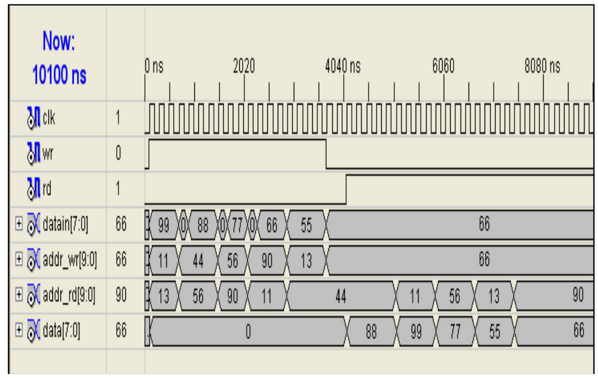


Figure 6 Simulation results of RAM

Table 1 Results for proposed architecture

Technology	Cmos 90 nm
Clock frequency	100 Mhz
Power consumption	152 mW
Memory size	174572 kB

Table 2 Performance comparison of proposed fusion method in terms of quality metrics

Methodology	PSNR	MSE	ENTROPY
Proposed methodology	56.23	27.41	2`098
Group-sparse algorithm	29.54	32.56	1.78
Bivariate module	22.16	37.19	1.96

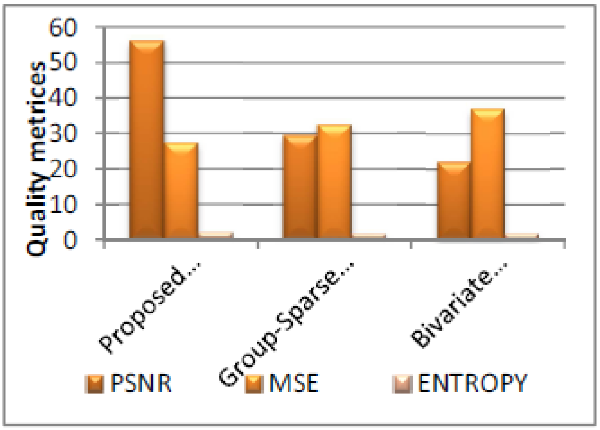


Figure 6 Graphical Representation of the Performance Comparisons in terms of PSNR, MSE and ENTROPY

7.0 CONCLUSION

In this study the implementation of wavelet based medical image fusion is suitable for medical diagnosis has been presented. The hardware implementation of a fusion method that is suitable for medical diagnosis has been presented. The hardware realization of our proposed fusion technique is based on FPGA technology and provides a fast, compact and low-power solution for medical image fusion. The hardware realization of our proposed fusion technique is based on FPGA technology and provides a fast, compact and low-power solution for medical image fusion. The dedicated sections provide a detailed description of the methodology to transform the wavelet based fusion method in a hardware realizable process. Future work in this field has been planned in extending the algorithm to other types of image modalities and to objectively evaluate image fusion methods in real time. The dedicated sections provide a detailed description of the methodology to transform the wavelet fusion method in a hardware realizable process. Future work in this field has been planned in extending the algorithm to other types of image modalities and to objectively evaluate image fusion methods in real time.

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