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FPGA Implementation of Image Fusion Technique Using DWT for Micro Air Vehicle Applications

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Abstract

The vital and increasing role of unmanned autonomous vehicles (UAVs) throughout the military applications is now well appreciated. Multiple onboard sensors on UAV are used to collect data and they are fused to extract information. In recent years, significant attention has been focused on multi-sensor data fusion for both military and nonmilitary applications. In this work instead of using various algorithms for image processing, DWT based processing is proposed for fusion. Lifting based algorithm is implemented on FPGA for Image fusion. DWT architecture based on modified lifting scheme is designed and is used in image fusion. The input images of size 100 x 100 have been chosen to validate the proposed fusion algorithm based on DWT.

Key Words: Unmanned Autonomous Vehicles, Micro Air Vehicle, Image fusion, DWT for imaging.

1. INTRODUCTION

1.1 Unmanned Autonomous Vehicles

Micro air vehicle (MAV), or micro aerial vehicle, is a class of unmanned aerial vehicles (UAV) that has a size restriction and may be autonomous. Modern craft can be as small as 15 centimeters. Development is driven by commercial, research, government, and military purposes with insect-sized aircraft reportedly expected in the future. The small craft allows remote observation of hazardous environments inaccessible to ground vehicles. MAVs have been built for hobby purposes, such as aerial robotics contests and aerial photography. An MAV would have an operating range of several kilometers and transmit detailed pictures back to a portable base station and many MAVs would be used and each of them would have different types of cameras and hence the captured data would be down linked to the base station image fusion is carried out.

1.2 Image fusion

Image fusion utilizes information obtained from a number of different sensors surveying an environment to achieve refined information for decision making. Information fusion can be performed at any level of the image information representation. Corresponding to other forms of information fusion, image fusion is usually performed at one of the three different processing levels

1. Signal
2. Feature
3. Decision level.

The Figure 1 shows the image fusion processing levels which consist of N image sequence as input .coe file, single image process which does the feature extraction of the input image and fusion process are carried out by three levels in image fusion domain.

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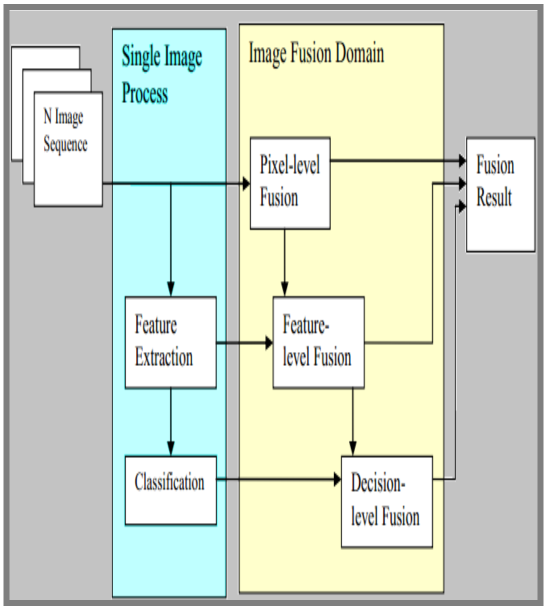

Figure 1. Image fusion processing levels

Signal level image fusion is also known as pixel-level image fusion which represents fusion at the lowest processing level, where a number of raw input image signals are combined to produce a single fused image signal (Vladimir 2001).

Feature level image fusion is also known as object level image fusion where it fuses feature and object labels and property descriptor information that have already been extracted from individual input images.

Decision level is also known as symbol level. Decision level is the highest level, where it represents fusion of probabilistic decision information obtained by local decision makers operating on the results of feature level processing on image data produced from individual sensors (Vladimir 2001).

There are many image fusion methods like averaging, principle component analysis and various types of Pyramid Transforms, Discrete cosine transform, Discrete Wavelet Transform special frequency and so on, are available and are classified according to processing level.

2. DWT BASED IMAGE FUSION

The requirement for the successful image fusion is that images have to be correctly aligned on a pixel-by-pixel basis. In this project, the images to be combined are assumed to be already perfectly registered. The Figure 2 shows the top level block diagram of image fusion using wavelet transform.

The two input images image1and image 2 that are captured from visible and infrared camera respectively are taken as inputs. The wavelet transform decomposes the image into low-low, low-high, high-low, high-high frequency bands. The wavelet coefficients are generated by applying the wavelet transform on input images. Wavelet coefficients of the input images are fused by taking the average of input images. The resultant fused image is obtained by applying the inverse wavelet transform.

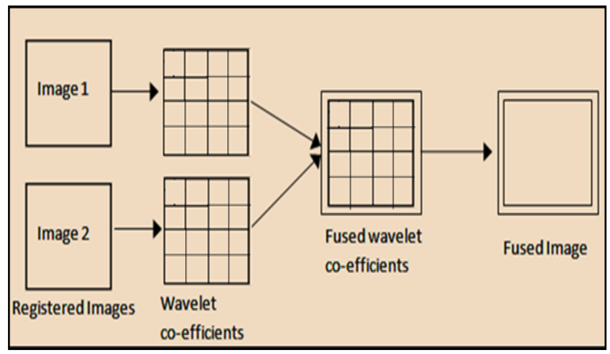

Figure 2.Block diagram of DWT based image fusion

The Figure 3 shows the flow chart to develop the image fusion process. The function developed to perform the image fusion, called wavelet and has four basic blocks:

Step 1: images size checking.

Step 2: transform to wavelet domain.

Step 3: wavelet domain fusion.

Step 4: inverse wavelet transforms.

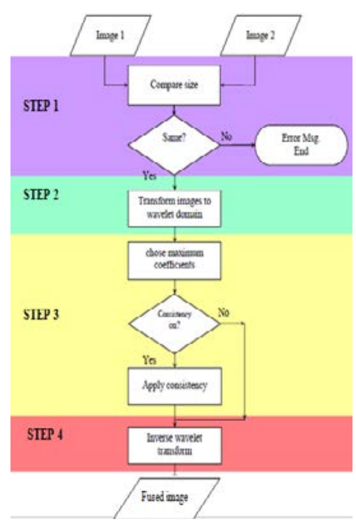

Figure 3. Flow chart for DWT based image fusion process

The most complex and significant step in this algorithm is to carry out the wavelet transformation. The wavelet transforms are applied to images. The wavelet transform consists of low-high, the high-low and high-high frequency bands of the image at different scales (Vladimir 2001). Since larger absolute transform coefficients correspond to sharper brightness changes and a good fusion rule to be selected at every point in the transform domain. The fusion takes place in all the resolution levels and main features at each scale are conserved in the new multi-resolution representation. Finally, a new image is constructed by applying inverse wavelet transform on fused image.

Due to compactness, orthogonality and availability of directional information, the DWT can successfully extract the main features at different scales.

The wavelet transform based image fusion technique produces the more naturally fused image even when the images to be combined are very different. An area–based maximum selection rule and a consistency verification step are proposed for feature selection. Better fusion results, both visually and quantitatively can be achieved using wavelet transform when compared to averaging and lapacian pyramid based image fusion (Manjunath 2008)

Wavelet-based image fusion technique is more robust under transmission and decoding errors, and also facilitates progressive transmission of images. Wavelet based fusion at higher compression avoid blocking artifacts. The designing and modeling of fusion of two images has been performed by averaging and 2-D DWT with different filters like Haar, Daubechies and Biorthogonal filters in MATLAB Simulink. The results of all fusion techniques for different set of images have been carried out. High PSNR and clear fused image has been achieved by 2-D DWT with 9/7 Daubechies filter.

3. HARDWARE IMPLEMENTATION

DWT architecture based on modified lifting scheme is designed and is used in image fusion. The input images of size 100 x 100 have been chosen to validate the proposed fusion algorithm based on DWT.

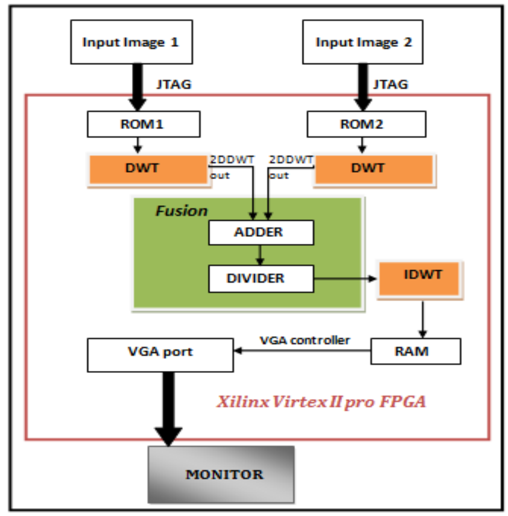

Figure 4. Top level block diagram of hardware implementation

Specifications

- Input image size - 100x100
- Input data - 24bit
- Input Clock - 40MHz
- Input file - .Coe
- ROM depth - 10,000

The wavelet transforms of the images has been computed. The registered images have been passed as input signals through two different one-dimensional digital filters H0 and H1 respectively. H0 and H1 digital filters perform high pass and low pass filtering operations respectively for both the input images. The output of each filters are followed by sub-sampling by a factor of 2. This step is referred as the Row compression and resultant is called as L-low frequency component and H-high frequency component. The down sampled outputs have been further passed to two one dimensional digital filters in order to achieve Column compression. The HH-High High, HL-High Low, LH-Low High and LL-Low Low are the output frequency components obtained after two level compressions of both the input images. The Figure 10 shows the block diagram of DWT based image fusion process which consists of two input images, DWT block, fusion block and IDWT block. The HH, HL, LH and LL frequency components of one input image is fused with the HH, HL, LH and LL components of second image respectively. HH components of both images have been added and then the resultant output has been divided by a factor 2. Similarly, the average of HL, LL and LH

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components has been taken. This process is known as Image Fusion. This averaged result has been future followed by the reconstruction process i.e., inverse wavelet transform. IDWT is the reverse process of DWT. In IDWT process, the HH, HL, LH and LL components have been first up-sampled and then filtering operation has been carried out. The sub-bands has been added or summed to get the resultant reconstructed image. The DWT based image fusion technique produced the more naturally fused image even when the images to be combined have been taken from different cameras.

4. RESULTS

Software simulation models have been developed using Simulink for image fusion and using DWT algorithm. Wavelet filters for fusion is chosen based on software simulation results that operate on various data sets. Based on the wavelet filter selected, low power high speed architectures are designed for 1D/2D DWT based Fusion is implemented in FPGA platform.

The Table 1 shows the PSNR values for the existing model and the developed 9/7 Daubechies filter based image fusion. The 9/7 Daubechies based image fusion has achieved same PSNR when compared with the existing model.

TABLE 1

Performance Comparison Of Existing Vs. Obtained Image Fusion

Input Images	PSNR	
	Existing	Proposed
Image set 1	150	170.83
Image set 2	128	168.85
Image set 3	148	168.56
Image set 4	132	170.92
Image set 5	141	166.2
Image set 6	156	172
Image set 7	168	178

The Fig. 7 shows the RTL schematic of 2D DWT block. Simulation results of this block is shown in Fig. 8.In this two images is taken and performed DWT of two images and given to Fusion block which is shown in Fig.9.

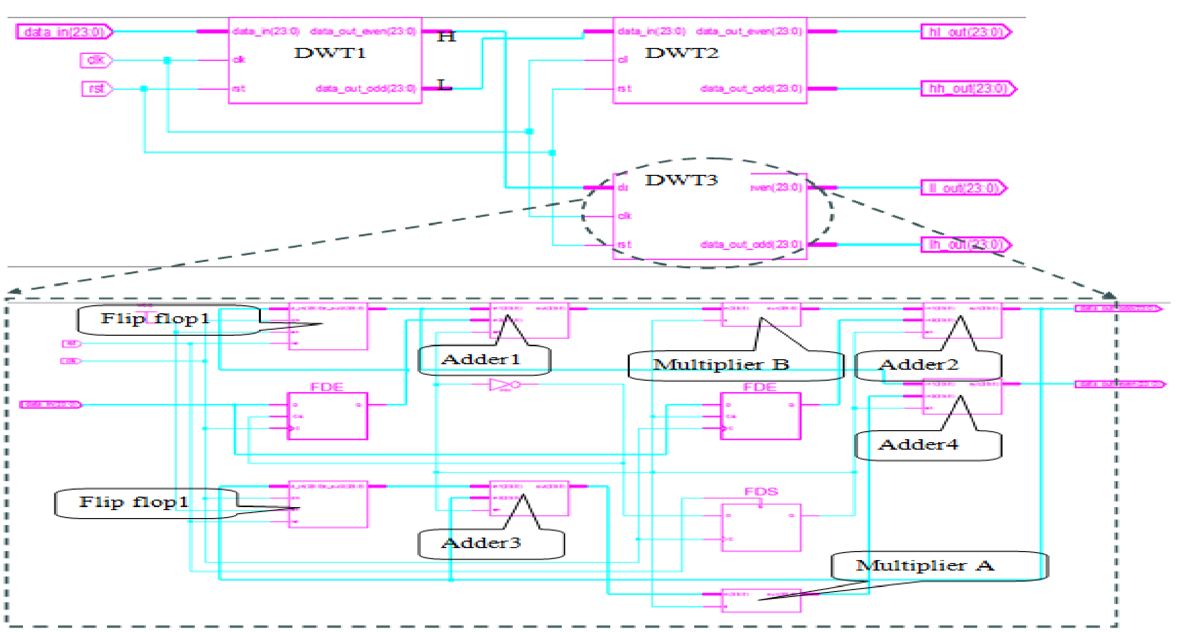

Figure 7. RTL schematic of 2D DWT

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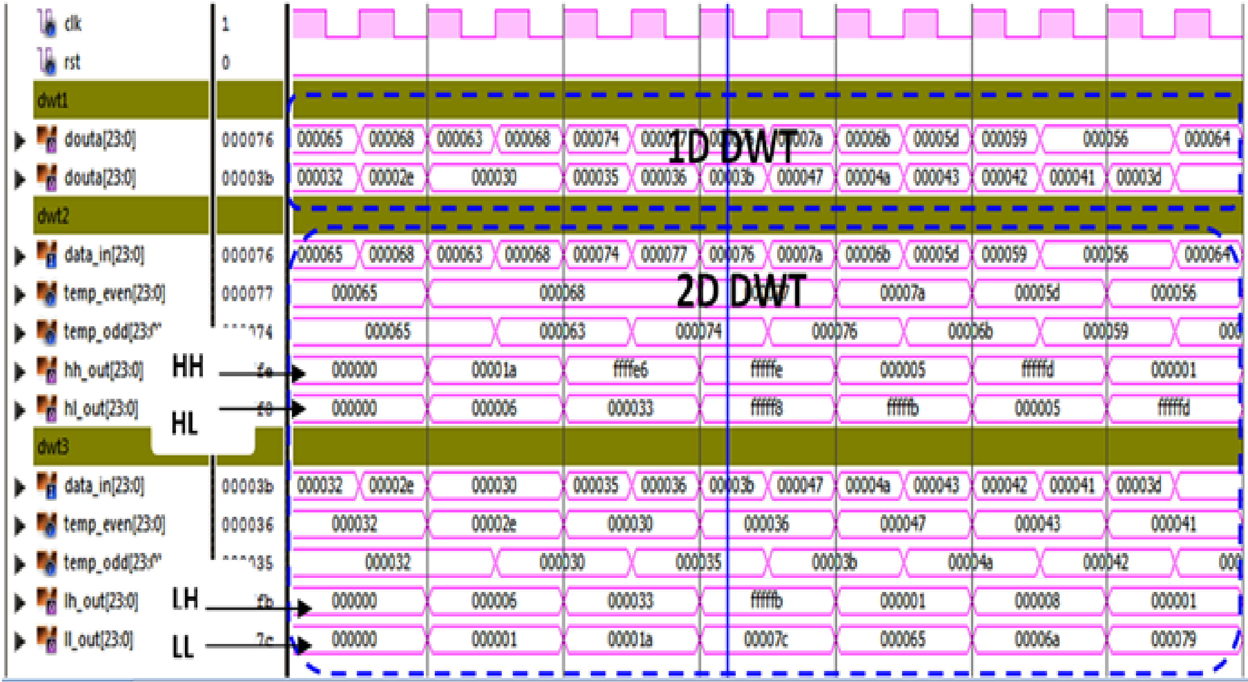

Figure 8. Simulation results of 2D DWT of both input images

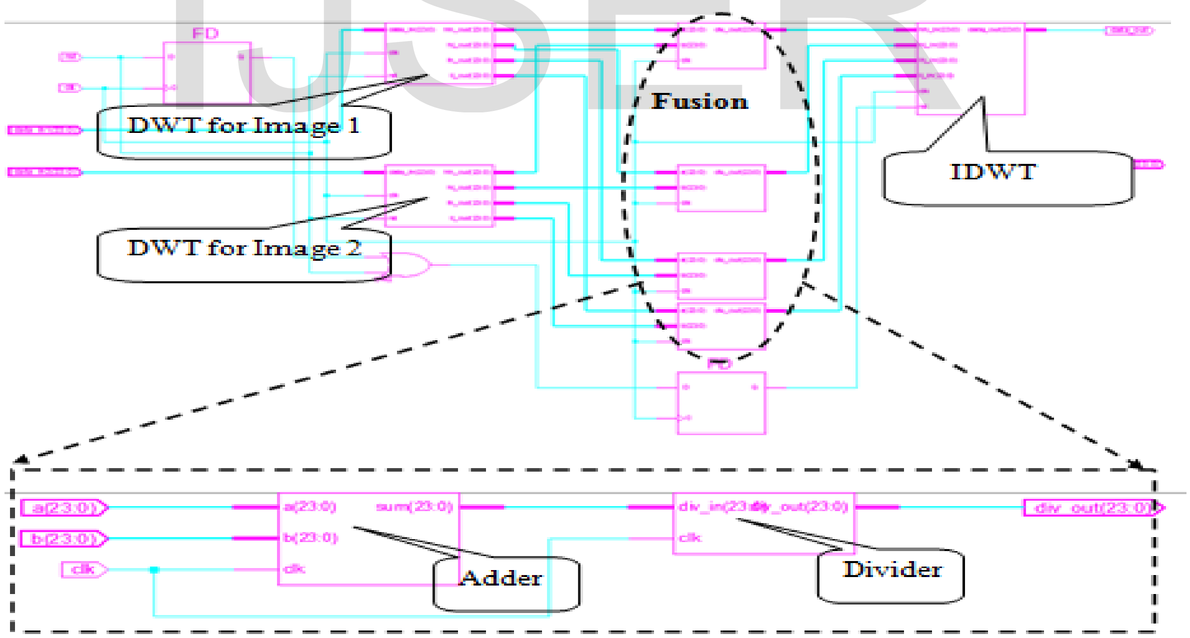

Figure 9. RTL schematic of Fusion process

The simulation results of fusion process is shown in Fig. 10.After fusion process passed through the 2D-IDWT block, the RTL schematic of IDWT is shown in Fig. 11.The simulation results of Fused image is shown in Fig. 12.

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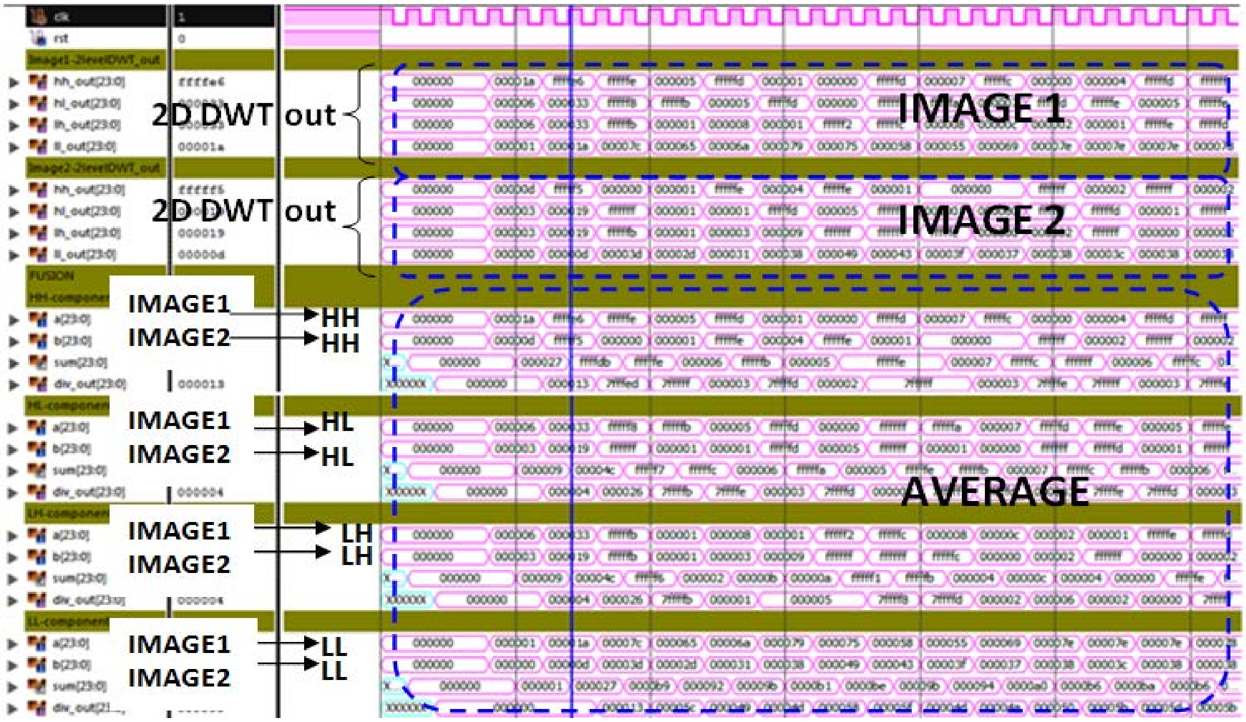

Figure 10. Simulation results of fusion process

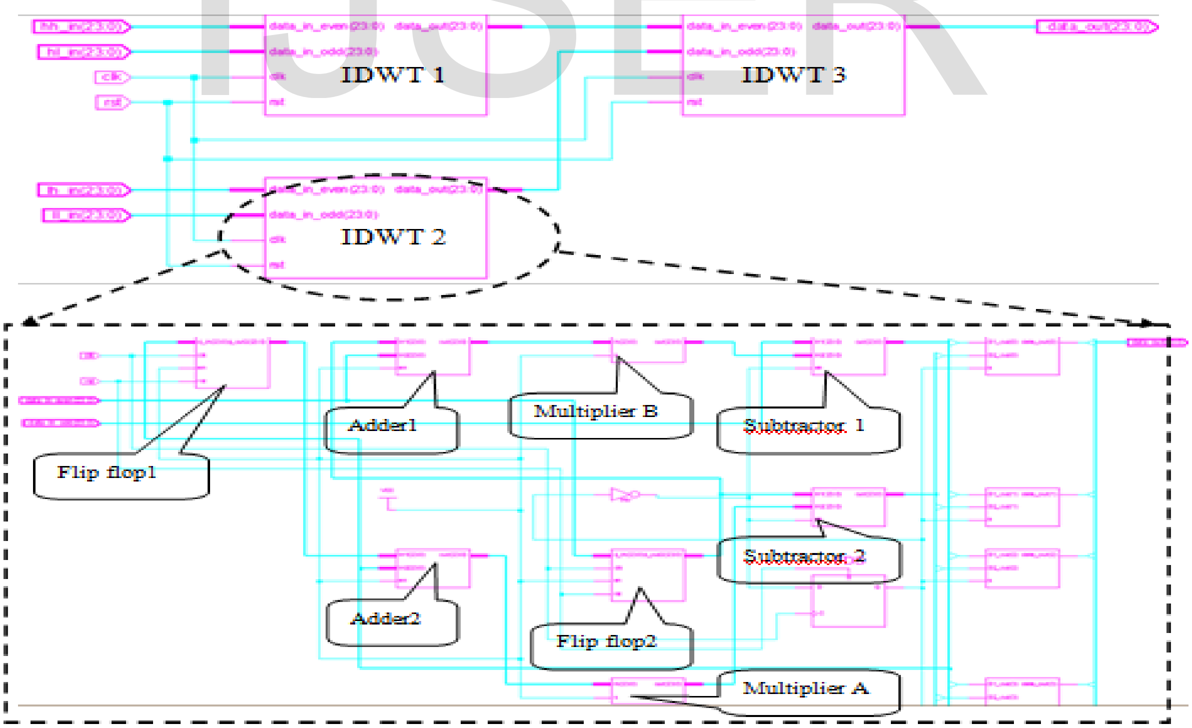

Figure 11. RTL schematic of 2D IDWT

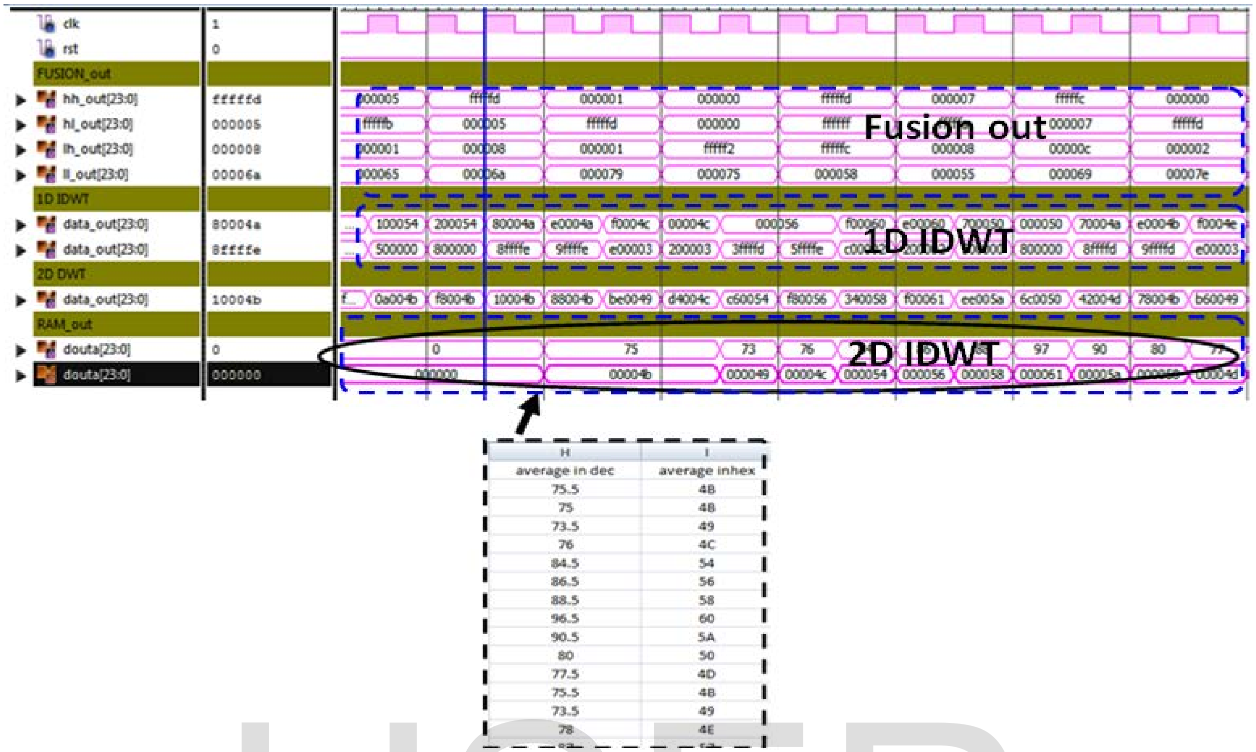

Figure 12. Simulation results of resultant fused image

The fusion algorithm on FPGA operates at 307 MHz, consumes power less than 0.21 W and occupies 436 slices. Table 2 shows the image fusion results using DWT on FPGA platform.

TABLE 2.

Fusion Hardware Results

Parameters	Reference design (Mohamed, M. A.)	Proposed work
Number of slices	456	436 (2%)
Number of IOBs	156	21 (4%)
Number of block RAMs	4	32(20%)
Maximum operating frequency	231 MHz	307 MHz
Maximum power dissipation	0.28W	0.21W

The DWT architecture based on modified lifting scheme algorithm is developing as an IP that can used for image processing applications. The design is optimized for area, power and speed performances and hence is suitable for high speed and low power applications. The ASIC implementation and FPGA implementation of the proposed design demonstrates the capabilities of the DWT IP for image processing applications on hardware platforms.

5. CONCLUSION

In this paper, Analysis was carried out to choose the type of image fusion technique that should has the property of orthogonality and should results in less MSE and high PSNR. The software reference model of the chosen architecture is developed in MATLAB Simulink 2011a.By observing the PSNR values of different types of fusion techniques like averaging and 2-D DWT with different filters like Haar, Daubechie and Bi-orthogonal, it is stated that Daubechie 9/7 results in higher PSNR vales.The hardware model for DWT can be developed for real time implementation optimizing for area, power and speed performances. The proposed design operates at frequency of 307 MHz and consumes power less than 0.21W, it improves 1.3 times speed and 25% of power with reference.

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