Comparison between FPGA implementation of Discrete Wavelet Transform and Dual Tree Complex wavelet Transform in Verilog HDL

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ABSTRACT

This paper presents a design of Dual tree Complex wavelet transform (DTCWT) implemented in VLSI architecture using Verilog HDL and result in verified in FPGA implementation which achieves approximate shift invariance and good directionality. As the wavelet transform has picked up considerable measure of prominence in field of signal processing. This is because of its ability of giving both time and frequency data at same time. It is depicted that operation achieved with precise processing speed of designed structure based at proposed scheme is ideal than the ones of the alternative architecture designed the use of other current schemes.

Keywords :- DSP, Dual tree Complex Wavelet Transform (DTCWT), FPGA, HDL, VLSI

I. INTRODUCTION

Over the recent couple of years execution of DSP work in FPGA has been expanding a result of their elite, straight forwardness to actualize and time to advertise them. One such is an execution of Discrete Wavelet Transform for image processing. A wavelet is a wave like oscillation with an amplitude that starts at zero, increments and after that declines back to zero. It can ordinarily be imagined as a brief oscillation like one recorded by seismograph or heart monitor. For the most part, wavelets are deliberately created to have particular properties that make them valuable for flag preparing. Wavelets are consolidated, utilizing a “reverse, shift, multiply and integrate” technique called convolution, with portions of a known signal to extract information from the unknown signal. Wavelets can be utilized to remove data from wide range of sorts of information, including-but certainly not limited to-audio signals and images. Sets of wavelets are for most part expected to dissect information completely.

A set of “complementary” wavelets will decompose data without gaps or cover so the deterioration procedure is scientifically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover original information with minimal loss. This representation is a wavelet series representation of square- integrable function with respect to either a complete, orthonormal set of basis functions, or an overcomplete frame of vector space, for the Hilbert space of square integrable functions.

A wavelet transform is similar to fourier transform with a totally extraordinary legitimacy work. The principle distinction is this: Fourier transform decomposes the signal into sines and cosines, in opposite wavelet transform uses functions that are localized in both real and fourier space. Generally, the wavelet transform can be expressed by following equation:

$$F(a,b) = \int_{-\infty}^{\infty} f(x)\varphi(a,b)(x)\,dx \qquad \text{----- (1)}$$

Wavelet transform are comprehensively partitioned into three classes: Continous, Discrete and multiresolution. In continous wavelet transform, a given signal of finite energy is projected on continous family of frequency bands. For instance the signal may be represented on every frequency band of form[f,2f] for all positive frequencies f > 0; it is computationally impossible to analyse a signal using all wavelet coefficients, so one may wonder it is sufficient to pick a discrete subset of upper half plane to be able to reconstruct a signal from corresponding wavelet coefficients. In any discretised wavelet transform, there are only a finite number of wavelet coefficients for each bounded rectangular region in upper halfplane. Still, each coefficient requires the evaluation of an integral. In special situations this numerical complexity can be avoided if scaled and shifted wavelets form multi resolution analysis. This means that there has to be exist an auxiliary function.

II. FPGA IMPLEMENTATION OF DISCRETE WAVELET TRANSFORM

Numerical and functional analysis demonstrates that the wavelets are discretely tested in DWT. A key favorable position a wavelet transform over other transform is that it can catch both location information and frequency which is more similar to human eye preparing framework. The DWT, which depends on sub-band coding, is found to yield a quicker calculation than regular wavelet transform and furthermore it can be executed effortlessly[4]. In DWT the signal at different frequency bands is analysed by decomposing the signal into detail and approximation information. The decomposition of signal can be done by filtering time domain signal using analyzing filters which consists of low pass and high pass filters[8]. The two filter outputs together contain same frequency content as input signal; however the amount of sampled data is doubled. Therefore down sampling by a factor two is applied to outputs of filters in analysis bank.

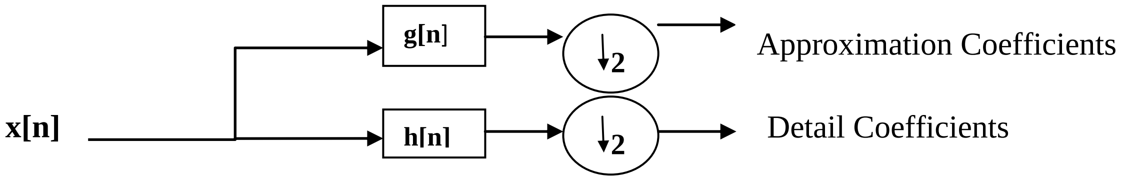

Fig1.1 Block Diagram of filter analysis

Fig 1.1 shows Block Diagram of filter analysis. The output giving the detail coefficients (from high pass filter) and approximation coefficients (from low pass). g[n] is low pass filter and h[n] is high pass filter.

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The DWT of signal x is calculated by passing it through a series filter. First the samples are passed through a low pass filter with impulse response g resulting in a convolution of two:

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k] \quad \text{---- (2)}$$

The filter output is given by:

$$ylow[n] = \sum_{k=-\infty}^{\infty} x[k]g[2n-k] \quad \text{----- (3)}$$

$$yhigh[n] = \sum_{k=-\infty}^{\infty} x[k]h[2n-k] \quad \text{----- (4)}$$

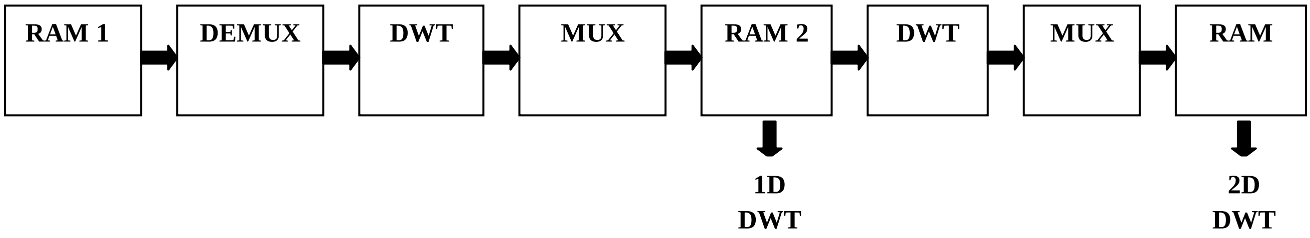

Fig.1.2 Block diagram of 2D-DWT

Suitable matlab command are used to get preprocessed input. Input image is converted to gray image of size 128*128.This pre processed input is given as contribution in Verilog HDL module. The input image is stored in RAM which is controlled by input RAM 1 controller. This stored data is perused and given as input to demux from this DWT module is figured with harr wavelet as transform. This initially iterated data is 1D yield, which requires promote calculation of next ;eve; to accomplish 2D calculation.

This information exhibit in RAM 2 is accessible for second cycle. The information is additionally perused from that point with the assistance of demux and facilitate it is send to DWT module for calculation and data is written in RAM with the help of multiplexer to get 2D DWT. This 2D DWT output is stored as text file read using matlab commands and demonstrate final output image i.e. 2D DWT transformed image. This transformed image is approved on FPGA equipment utilizing Xilinx and again process it to matlab to observe output image is whether 2D DWT or not.[2]

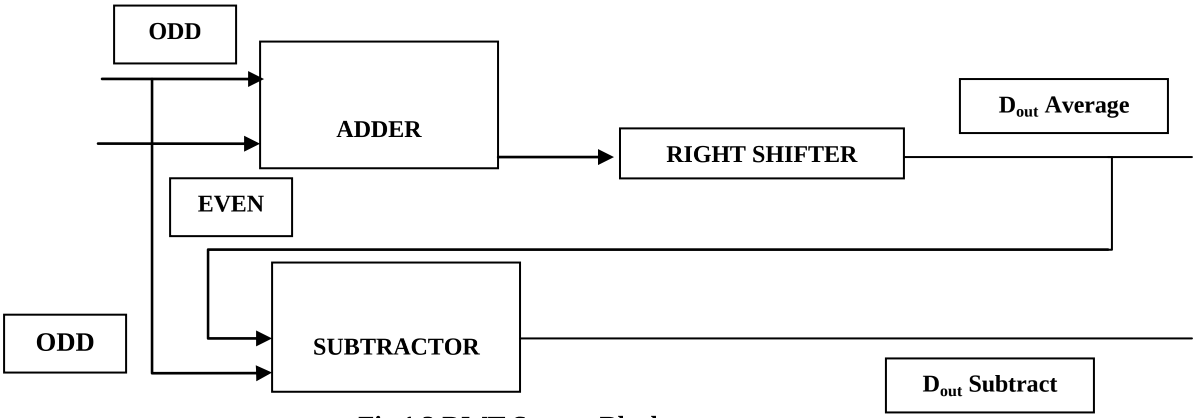

Fig.1.3 DWT System Block

III. FPGA IMPLEMENTATION OF DUAL TREE COMPLEX WAVELET TRANSFORM

The use of complex wavelets in image processing was originally set up in 1995 by J.M. Lina and L. Gagnon in the framework of the Daubechies orthogonal filters banks. The complex wavelet transform (CWT) is a complex-valued extension to the standard discrete wavelet transform (DWT)Dual tree complex wavelet transform is relatively recent enhancement to DWT with critical extra properties: It is nearly shift invariant and directionally selective in two and higher dimensions. It achieves this with a redundancy factor of only 2^d substantially lower than the undecimated DWT[1]. The multidimensional dual tree CWT is nonseparable but is based on computationally efficient, separable filter bank.

Making the wavelet responses analytic is a good way to halve their bandwidth and hence minimise aliasing. But we cannot use complex filters in to obtain analyticity and perfect reconstruction together, because of conflicting requirements[9]. Analytic filters must suppress negative frequencies, while perfect reconstruction requires a flat overall frequency response. So we use the Dual Tree:-

• to create the real and imaginary parts of the analytic wavelets separately, using 2 trees of purely real filters;

• to efficiently synthesise a multiscale shift-invariant filter bank, with perfect reconstruction and only 2:1 redundancy (and computation);

• to produce complex coefficients whose amplitude varies slowly and whose phase shift depends approximately linearly on displacement[12]

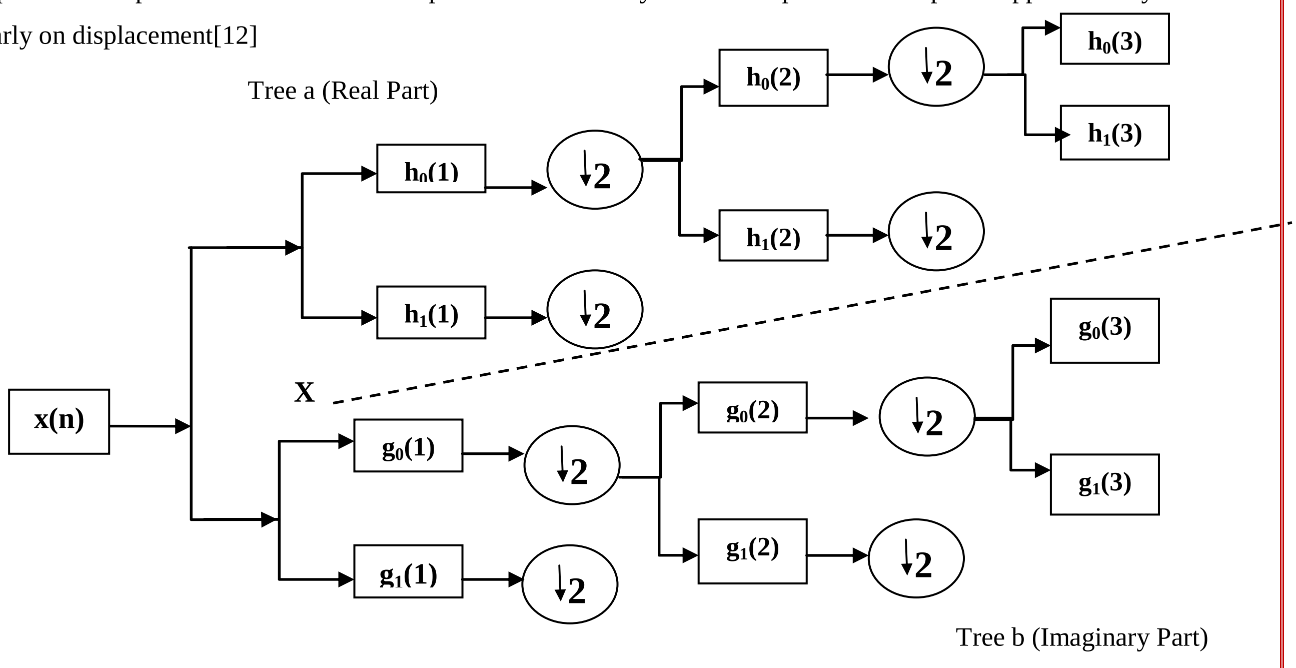

Fig.1.4 Block Diagram of 2D-DTCWT

In dual tree complex wavelet transform input image is decomposed into 16 levels by two separable 2D-DWT from which 12 are of high sub-bands and 4 are of low sub-bands [14]. As a result, sub bands of 2D DT-CWT at each level are obtained as:

(LHa + LHb) /√2, (LHa – LHb) /√2,

(HLa + HLb) /√2, (HLa – HLb) /√2,

(HHa + HHb) /√2, (HHa – HHb) /√2

Above flow diagram shows the proposed methodology. To begin with our aim we start our work with input image. The input image is processed into MATLAB with use of suitable commands to convert into its pixel values. The data is stored in internal memory using a text file which contain input image pixel values in Verilog. The design of DWT hardware use the concept of Harr transform because of simplicity and less hardware requirement for its implementation. In this algorithm average the two pixel values and this average will give average and difference component.

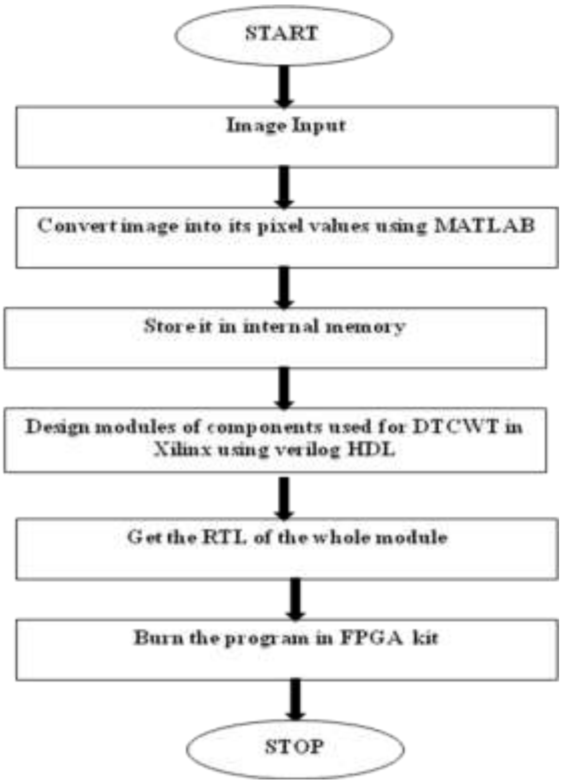

Fig. 1.5 Flow Diagram of Proposed system

IV.CONCLUSION

This paper highlighted design of DWT and dual tree complex wavelet transform (DTCWT) architecture. The computed system can be implemented in MATLAB and Verilog HDL, later on this result is validated on FPGA Spartan 6. The pixel values of input image where operated using harr wavelet transform. The result portrayed us that the proposed architecture provides better enhancement characteristics as compared to discrete wavelet transform. In Future we endeavor to execute proposed design calculation utilizing even less assets, utilizing diverse mother wavelet and analyse comes about on various equipment stage for accomplishing desired performance.

Table 1. Hardware Utilisation and characteristics Comparison

Parameters	**Discrete Wavelet Transform (DWT)**	**Dual tree Complex Wavelet Transform (DTCWT)**
No. of Slice registers	239	250
No. of Slice LUTs	394	400
Bonded IOBs	11	15
Block RAMs	24	35
Accuracy	low	high
Shift Invariance	poor	Nearly Approximate(Good)
Throughput	low	high
Selectivity	Poor	Good
Complexity	low	High compared to DWT
Cost	low	Quite high

Table I. shows comparison between hardware utilization and Characteristics of Discrete Wavelet Transform and Dual tree Complex Wavelet transform which concludes that DTCWT may uses more hardware but the quality of image and performance will be better than that of DWT.

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