Design and Implementation of Lifting Based Two Dimensional Discrete Wavelet Transform

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ABSTRACT

In this paper, an image compression using a lifting based 2D DWT is proposed and is implemented. The Discrete Wavelet Transform is a more efficient than the Discrete Fourier and Discrete Cosine Transform in terms of Noise, Compression ratio and Transmission speed. In order to overcome the noise and to achieve Higher Transmission speed, an improved version of lifting based Discrete Wavelet Transform VLSI architecture is proposed. In this lifting scheme- split, predict, update methods for lower computational complexities and higher efficiencies is used. Based on convolutions, the Traditional DWT architectures are designed. The second-generation DWTs, which is based on lifting algorithms, are proposed. The DWT is mainly used in image processing. Because, it supports features like progressive image transmission (by quality, by resolution), region of interest, ease of compressed image manipulation, etc. The process of image compression is performed in this paper. VLSI architecture is designed by using lifting based Discrete Wavelet Transform (DWT) and its Register Transfer Logic (RTL) is described using Verilog. The architecture operates at a frequency of 353.107 MHz, when synthesized for Virtex-IV series field programmable gate array using Xilinx 10.1
Keywords: Lifting Scheme, Discrete Wavelet Transform, Image Compression, VLSI Architecture, FPGA

1. INTRODUCTION

The discrete wavelet transform (DWT) has gained wide spread acceptance in signal coding, data compression, data interpretation, data hiding, audio signal processing, motion tracking, machine learning and so on. Unlike the discrete cosine transform, DWT has higher compression ratios, good localization in time and frequency domain, inherent scaling and higher flexibility. Many well-known very large scale integration (VLSI) architectures are proposed for convolution-based DWT.

Later the lifting-based DWT is used to reduce computational complexity. Lifting-based DWT has several advantages over convolution-based DWT including, faster implementation, integer coefficients, fully in place calculation of DWT, less hardware complexity and symmetric forward and inverse transform. DWT decomposes the image into multiple sub bands of low and high frequency components. The two-dimensional Discrete Wavelet Transform (2D DWT) is nowadays mainly used in image processing. Because it achieves faster transmission due to the sub band decomposition.

A 1D-DWT uses a 1D input vector and computes its wavelet transform. By using 1-D DWT 2D DWT is done easily. By applying a one-level, 1D-DWT along the rows of the image, and then apply a one-level, 1-D DWT along the column of the transformed image from the first step the 2D-DWT can be computed. This process splits the image into 4 parts LL, HL, LH, and HH. In this LL portion is a low resolution version of the original image.

2. LITERATURE SURVEY

A high speed, very low power, memory efficient, and dual memory scan based pipelined VLSI architecture for 2-D Discrete Wavelet Transform (DWT) based on Legal 5/3 filter is proposed. Moreover dual scan technique is mainly used to increase throughput with 100% hardware utilization efficiency without increase in power. Positive slack with 200 Mhz frequency is shown in   Simulation result. Core area is only 0.73 mm2 with low power consumption such as 13.38 mw in proposed architecture [5].A lifting based I-D Discrete Wavelet Transform (DWT) core is proposed. It is reconfigurable for Y3 and 9/7 filters in JPEG2000. In [8] proposed a Folded architecture to reduce the hardware cost

and achieve the higher hardware utilization. It is a compact and efficient DWT core for the hardware implementation of JPEG2000 encoder.

In [9] a novel low-complexity, VLSI architecture for image compression applications is proposed. By the accuracy of coefficients representation only the hardware implementation of the 9/7 filter bank is performed. The main aim of this work is to show that excellent performance with great complexity reduction can be achieved through the derivation of the 9/7 taps values. Memory requirements and critical path are essential issues for 2-D transforms. In [17] the 2-D dual-mode LDWT architecture is proposed, that has the merits of low transpose memory (TM), regular signal flow and low latency, making it suitable for very large-scale integration implementation. The $2N$ and $4N$ are the TM requirement of the $N{\times}N$ 2-D 5/3 mode LDWT and 2-D 9/7 mode LDWT respectively. Comparison results indicate that the proposed hardware architecture has a lower lifting-based low TM size requirement than the previous architectures. As a result, it can be applied to real-time visual applications such as motion-JPEG2000, JPEG2000 , MPEG-4 still texture object decoding.

In [12] an efficient VLSI architecture, called flipping structure, is proposed for the lifting-based discrete wavelet transform. It provides a variety of hardware implementations to minimize the critical path as well as the memory requirement by flipping conventional lifting structures. The idea behind the lifting scheme is that, a new construction of biorthogonal wavelets that does not use the Fourier Transform. When compared with earlier papers, lifting from a wavelet transform is introduced. Consider the wavelet basis functions in a later stage. Lifting leads to a faster, fully in-plane implementation of the wavelet transform is shown here. Moreover, it can be used during the construction of second generation wavelets. A example of the wavelets on the sphere in[10].

3.METHODOLOGY
3.1 Discrete Wavelet Transform
DWT has higher compression ratios, good localization in time and frequency domain, inherent scaling and higher flexibility. Owing to such inherent advantages of DWT, two dimensional (2D) bi-orthogonal reversible/irreversible DWT is adopted in JPEG2000 still image compression standard and transform coder in MPEG-4 still texture coding. DWT is one of the fastest computations of wavelet transform and easy to implement and reduces the computation time and resources required. DWT is a very useful tool in time-frequency analysis. Because, it has excellent localization both in time and frequency domain. It has been very successful in areas like image compression, de-noising and communication. It is a good alternate method to FFT (Fast Fourier Transform) in many applications.

Because of the good reconstruction property, DWT is more efficient. It can be used in several medical applications, like monitoring of fetal heartbeats, analyzing electrocardiograms, Ultrasounds. It is used to compress the sequence of images and   obtained best results in DWT because of its simplicity.

A signal is decomposed into a set of basic functions by Wavelet transform. These basic functions are called wavelets. Wavelet is obtained from a single prototype wavelet called mother wavelet by shifting. The DWT has been considered as a easy method and highly efficient for sub band decomposition of signals. In Discrete Wavelet Transform, the signal energy concentrates to specific wavelet coefficients. This characteristic is useful for compressing images.

Typically an image is assumed to have a spectrum that decays with increasing frequency. In an n-level decomposition of an image, the lower levels of decomposition would correspond to higher frequency sub bands. In particular, level frequency sub bands. In particular, level one would represent the highest frequency sub bands and would be the finest level of resolution. Conversely, the n-th level would correspond to the lowest level frequency sub bands and would correspond to the lowest resolution. The two dimensional transformation is the simple extension of the one-dimensional transform which is done by filtering the image both horizontally and vertically i.e, the 2-D transform can be computed by applying 1-D transform to all the rows of input , and then repeating on all of the columns. The resulting transformed image now contains four sub bands LL1,LH1,HL1 and HH1, standing for low-low, low-high, high-low and high-high as shown in Figure 1 . The distribution in the lowest frequency sub band has the same properties as the distribution in original picture, expect that range is approximately twice as wide due to energy concentration.

LL1	HL1
LH1	HH1

Figure 1: Discrete Wavelet Transform

3.2 Lifting Scheme
The Lifting scheme (LS) is considered as an efficient method to simplify the performance of wavelet transform. It has some advantages when compared with classical filter banks method, such as the simple and fast hardware implementation, the fewer and simpler arithmetic computations required, the ease of inverse implementation, occupying less memory storage. In addition, it is more appropriate for high speed and low power applications such as the image/video processing applications.

International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org

Volume 5, Issue 1, January 2016   **ISSN 2319 - 4847**

The Lifting scheme (LS) can be performed by three steps: (i)the split stage, (ii)the predict stage, and (iii) the update stage. In the split stage the input signal or image is splits into even and odd indexed samples. The computations of high pass filter coefficients is done in the predict stage which representing the details sub band. Finally ,the update stage gives low pass filter coefficients of the DWT process.
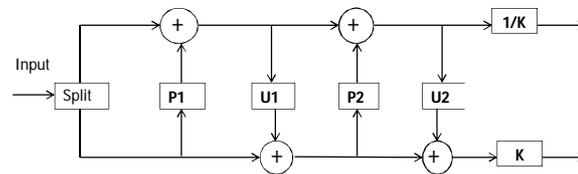

Figure 2: Lifting Architecture

3.3 Lifting Based 2D DWT

The lifting scheme is attractive for high throughput and low-power VLSI applications. In general, it has three steps: split, predict and update. The lifting steps is shown in Fig 3; each lifting step consists of one predict and one update step denoted as P1, P2 and U1, U2, respectively. The principle used in lifting process is to divide the polyphase matrices of wavelet filters into sequences of upper and lower triangular matrices and then convert the filter implementation into banded matrices multiplication.

The various architectures are analyzed in terms of hardware and timing complexity involved with the given size of input image and required levels of decomposition. This study is useful for deriving an efficient method for improving the speed and hardware complexities of existing architectures and to design a new hardware implementation of multilevel DWT using lifting schemes. To construct wavelet basis the lifting scheme is introduced as a new method.

The lifting scheme depends on the spatial domain only. It has many advantages when compared with filter bank structure, such as low power consumption, less area, and computational complexity. It can be easily implemented by hardware with reduced computations which is shown in Fig.3. It has other advantages, such as integer-to-integer wavelet transforms, "in-place" computation of the DWT, which is useful for lossless compression coding.

The lifting scheme has been introduced as a flexible and efficient tool and it is suitable for constructing the second generation wavelets. It consists of three basic operation stages: (i)split, (ii)predict and (iii) update. Fig 3 shows the lifting process of the wavelet filter for computing one dimension signal.
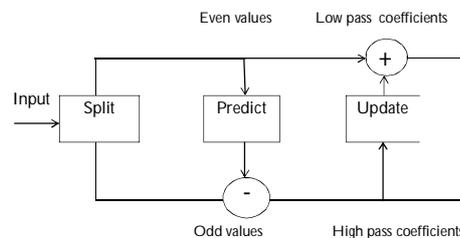

Figure 3: Lifting process of DWT

Lifting based DWT consist of three basic steps.
They are,

1.Split: The signal is decomposed into even and odd points. Where the maximum correlation between adjacent pixels can be used for the next predict step. Every pair of input samples x(n) split into even x(2n) and odd coefficients x(2n+1).

2. Predict: After multiplying the even samples by the predict factor , the results are added to the odd samples to generate the detailed coefficients. Detailed coefficients gives high pass filtering

3. Update: Multiply the detailed coefficients obtained in the predict step with the update factors and then the results are added to the even samples to generate the coarse coefficients. The coarser coefficients results in low pass filtered output.
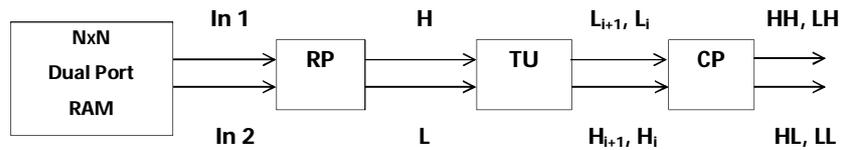
International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 5, Issue 1, January 2016 **ISSN 2319 - 4847**

Figure 4: Overall block diagram of the lifting-based 2D DWT architecture

The overall block diagram of the lifting-based 2D DWT architecture is shown in Fig.4 The proposed architecture consists of a 1D row processor (RP) and column processor (CP) to perform 1D DWT in both row and column wise along with a transposing unit (TU). A temporal memory is used to store the intermediate 1D row processed coefficients.

4.RESULT AND DISCUSSION

Simulation for the proposed technique has been performed by using the Modelsim6.5e. Power, area for Lifting Based DWT algorithm are analyzed in Cadence 180 nm technology is shown in Table 1.

The process of Lifting Based DWT in Matlab is shown in Fig 5. Directly the image cannot given as a Input in Xilinx. so, the conversion process done in Matlab which is shown in Fig 6 and Fig 7. The Input pixel value is splitted in four sub bands LL,HL,LH,HH bands that is shown in Fig 8. Lifting Based DWT algorithm is implemented and RTL of the design is described using Verilog and synthesized using Xilinx ISE 10.1 is shown in Fig 9.
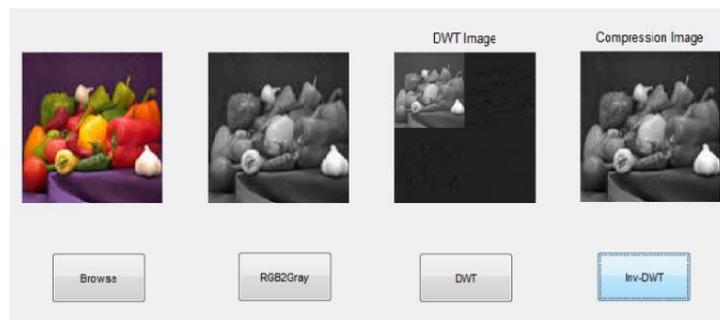

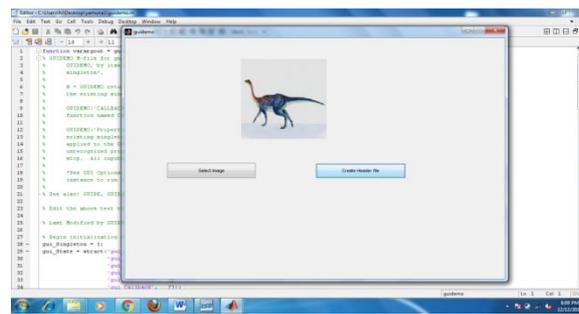**Figure 5:** Matlab Result for DWT process
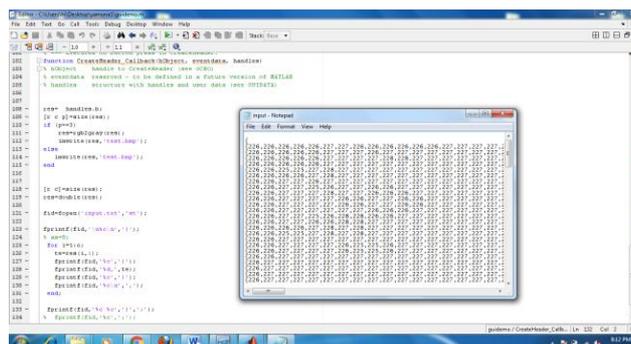

Figure 6: Input Image

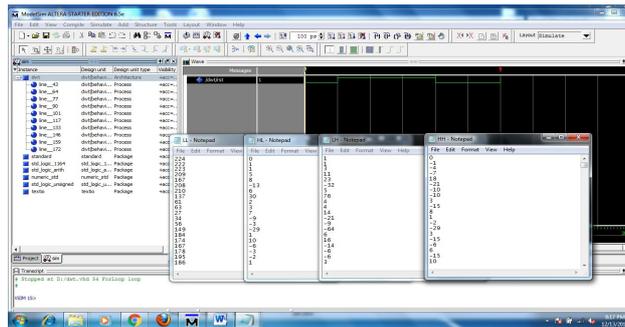**Figure 7:** Conversion from Input Image to Pixel Values

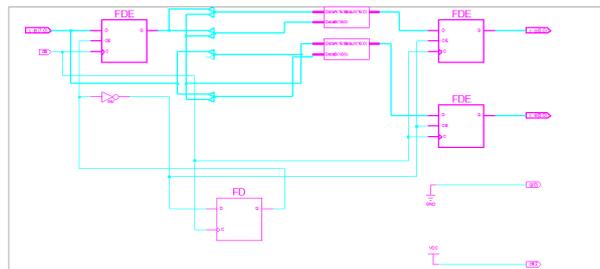**Figure 8:** Pixel values of LL,HL,LH,HH Bands

Figure 9: RTL view of Lifting based DWT

Table 1 Cadence – report for Lifting based DWT

Total number of Gates	Leakage Power (nw)	Dynamic Power (nw)	Total Power (nw)	Area
52	1673.121	58285.901	59959.021	526

5. CONCLUSION

To overcome the noise present in DCT and for Faster transmission of signal,DWT is used. Area and Power of the hardware implementation is studied. Lifting Based 2D DWT algorithm is implemented and RTL of the design is described using Verilog and synthesized using Xilinx ISE 10.1. when synthesized for Xilinx Virtex-IV series field programmable gate array , the operating frequency of the proposed architecture is 353.107 MHz,. The simulation is done using Modelsim6.5e.

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International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 5, Issue 1, January 2016   **ISSN 2319 - 4847**

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