Implementation Of 3D DWT With 5/3 LeGall Filter For Image Processing

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***Abstract*—The discrete wavelet transform (DWT) is being increasingly used for image coding 3D-DWT provides interesting possibilities and has been studied to resolve the problem associated with compression of large size images. However, the main issue of concern is preserving more details in the enlarged image. On the problem that the hardware overhead in architecture for Convolution based DWT wastes a lot which is replaced here with a multiplierless design .This can be achieved with lifting approach with shifters and adders/subtractors replacing multipliers. Thus giving less number of Computations and makes control complexity very simple. This paper presents an efficient 3D-DWT (three-dimensional discrete wavelet transform) architecture of lifting based 3D DWT in FPGA which uses LeGall 5/3 filter. The lifting structure largely reduces the number of multiplication and accumulation where filter bank architectures can take advantage of many low power constant multiplication algorithms. FPGA is used in general in these systems due to low cost and high computing speed with reprogrammable property .The 3D DWT processor was designed in VHDL and implemented with a Xilinx Virtex-III FPGA.**

***Keywords*-3D DWT, multiplier less, lifting based 5/3 LeGall filter, VHDL**

I. INTRODUCTION

The Discrete Wavelet Transform (DWT) is well-suited for multi resolution analysis. The basic idea of 3-D architecture is similar to 1-D architecture. The 3-D DWT is like a 1-D WT in three directions. First, the process transforms the data in the x-direction. Next, the low and high pass outputs both feed to other filter pairs, which transform the data in the y-direction. These four output streams go to four more filter pairs, performing the final transform in the z-direction. The process results in 8 data streams. The approximate signal, resulting from scaling operations only, goes to the next octave of the 3-D transform. Three-dimensional data, such as a video sequence, can be compressed with a 3-D DWT.

The basic idea of lifting scheme is first to compute a trivial wavelet (or lazy wavelet transform) by splitting the original 1-D signal into odd and even indexed subsequences, and then modifying these values using alternating prediction and updating steps. The lifting scheme algorithm can be described as follow:

i. Split step: The original signal, X(n), is split into odd and even samples (lazy wavelet transform).

ii. Lifting step: This step is executed as N sub-steps (depending on the type of the filter), where the odd and even samples are filtered by the prediction and update filters, Pn(n) and Un(n).

iii. Normalization or Scaling step: After N lifting steps, a scaling coefficients K and 1/K are applied respectively to the odd and even samples in order to obtain the low pass band ($Y_L(i)$), and the high-pass sub-band ($Y_H(i)$) as shown in Figure 3. The lifting scheme requires fewer computations compared to the Convolution based DWT. Therefore the computational complexity is reduced to almost a half of those needed with a convolution approach [3] [5]. As a result, lifting has been suggested for implementation of DWT in JPEG2000 standard.

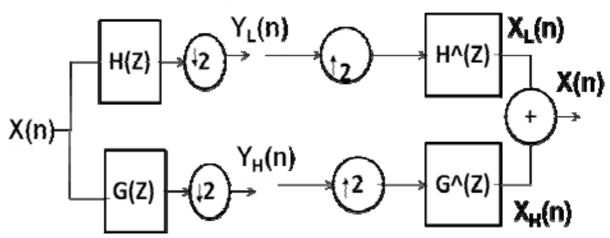

Fig. 1. Convolution based 1 D DWT block

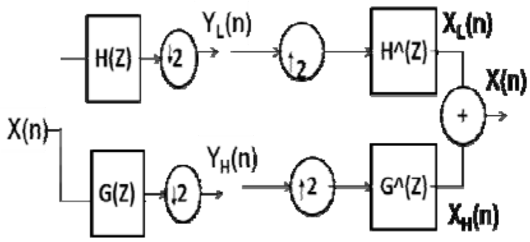

Fig. 2. The lifting scheme of the 1D-DWT

II. DWT WITH 5/3 LEGALL FILTER

There are two lifting steps in the forward 5-3 LeGall wavelet transformation [1]. The lifting steps and range of the variable *n* are given in Equation 1. Given integer input data, the 5-3 wavelet will produce integer output data. The 5-3 lifting steps alternately predict and update the even and odd samples in the output array Y(i).The output

array, Y(i), contains low-pass and high-pass samples in interleaved form. If i0 is even, the first sample in Y(i) is low-pass (low-pass first). If i0 is odd, the first sample is high-pass (high-pass first). The last sample in Y(i) is low-pass or high-pass depending upon whether i0 is even or odd and the length of Y(i) (i1 – i0). The lifting steps for the 5-3 wavelet and the range of variable, n, given the index range of X(i), (i0, i1) is shown in (1).

$$\begin{aligned}
&\text{Step1 :}\\
&Y(2n+1) = Xext(2n+1) - \frac{\{Xext(2n) + Xext(2n+2)\}}{2} \qquad \text{For } \left\lfloor \frac{i0}{2} \right\rfloor - 1 \le n < \left\lfloor \frac{i1}{2} \right\rfloor\\
&\text{Step2 :}\\
&Y(2n) = Xext(2n) + \frac{\{Y(2n-1) + Y(2n+1) + 2\}}{4} \qquad \text{For } \left\lfloor \frac{i0}{2} \right\rfloor \le n < \left\lfloor \frac{i1}{2} \right\rfloor
\end{aligned} \tag{1}$$

The lifting steps for the Inverse 5-3 wavelet and the range of variable, n, given the index range of Y(i), [i0, i1) as shown in (2).

$$\begin{aligned}
&\text{Step1 :}\\
&X(2n) = Yext(2n) - \frac{\{Yext(2n-1) + Yext(2n+1)\}}{4}\\
&\text{For } \left\lfloor \frac{i0}{2} \right\rfloor \le n < \left\lfloor \frac{i1}{2} \right\rfloor + 1\\
&\text{Step2 :}\\
&X(2n+1) = Yext(2n+1) + \frac{\{X(2n) + X(2n+2)\}}{2} \qquad \text{For } \left\lfloor \frac{i0}{2} \right\rfloor \le n < \left\lfloor \frac{i1}{2} \right\rfloor
\end{aligned} \tag{2}$$

III. IMPLEMENTATION OF 3-D DISCRETE WAVELET TRANSFORM

This section deals with hardware implementation of the wavelet transform which require mainly three different modules which are explained in detail in the preceding sections. One is the memory module which is required for storing the original input image pixel coefficients as well as to store the resultant transform coefficients, the size of the memory should be twice of the image size since memory stores input image pixel coefficients as well as resultant transform coefficients. The input coefficients are filled into the memory directly from the input file where the image coefficients are stored, the resultant transform coefficients are dumped into the output file. Second is the RWTU (reversible wavelet transform unit) since this transform is completely reversible we call this module as reversible. The function of this module is to fetch the input pixel coefficients from the memory with the help of control signals generated by the control unit and perform the computation as required for lifting scheme. The computed transform coefficients are again stored back into the memory [1].

The 3D DWT compression will give the best (most visually pleasing) results while still allowing a good compression ratio. The 3-D WT is like a 1-D WT in three directions. First, the process transforms the data in the x-direction. Next, the low and high pass outputs both feed to other filter pairs, which transform the data in the y-direction. These four output streams go to four more filter pairs, performing the final transform in the z-direction. The process results in 8 data streams. The approximate signal, resulting from scaling operations only, goes to the next octave of the 3-D transform. Three-dimensional data, such as a video sequence, can be compressed with a 3-D DWT. Most applications today perform a 2-D DWT on the individual images and then encode the differences between images with difference coding. Given the first image, followed by the differences between the first and second frame, the second image can be constructed. For an image sequence with little change, such as a video of a person speaking, this method works well. For other sequences, such as medical imaging, the image sequence will have more changes between frames. Thus a true 3-D method would work better. Applying 3D-DWT is not easy; the difference between 2D images and 3D volumes is the third dimension (depth or Z-axis). The expected transform after applying one decomposition level of 3D-DWT is illustrated in Fig.5. Applying one level of 3D-DWT is the process of transforming the original volume into 8 octants in its wavelet domain. Mathematically, 3D-DWT is the process of applying 1D-DWT on each vector in Z-axis which has the same X-axis and Y-axis coordinates after applying 2D-DWT for all comprising frames.

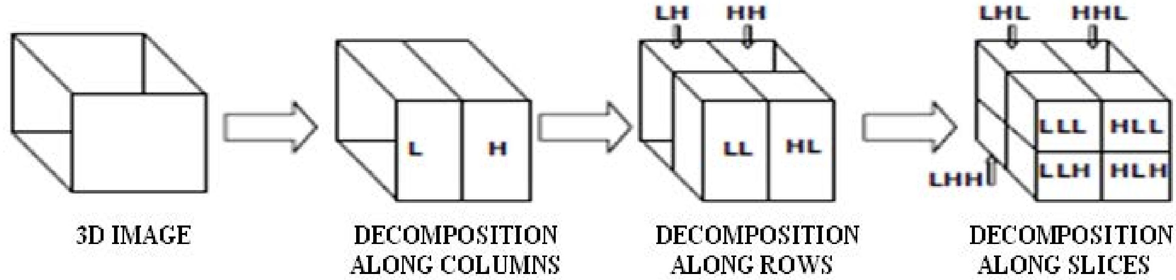

Fig. 3 Decomposition of 3D DWT

Fig.4 shows a separable 3D decomposition of a volume. The volume F(x, y, z) is firstly filtered along the x dimension, resulting in a low-pass image L(x, y, z) and a high-pass image H(x, y, z). Since the size of L and H along the x dimension is now half that ofF(x, y, z), down-sampling of the filtered volume in the x dimension by two can be done without loss of information. The down-sampling is done by dropping each odd filtered value. Both L and H are then filtered along the y dimension, resulting in four decomposed sub-volumes: LL, LH, HLand HH. Once again, we can down-sample the sub-volumes by two, this time along the z dimension. Then each of these four sub-volumes are then filtered along the z dimension, resulting in eight sub-volumes: LLL, LLH, LHL, LHH, HLL, HLH, HHL and HHH.

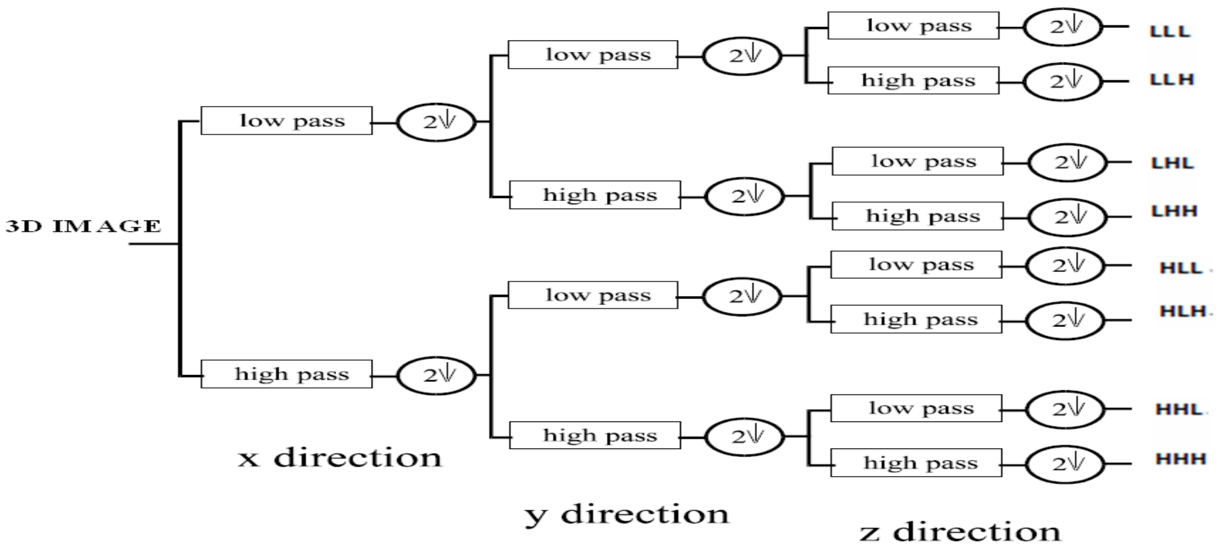

Fig.4. The 3-D Discrete Wavelet Transform

After modifying the coefficients we can apply the inverse transform by convolving with the respective low-pass and high pass synthesis filters and u psampled by 2.i.e. the lowest low-pass and high pass data-streams are up-sampled and then filtered using filters related to the decomposition filters as shown in fig.5. In forward DWT down sampling was done whereas in inverse DWT up sampling is done to reconstruct the signal and the implementation is done like forward DWT which is exactly inverse.These coefficients correspond to H and L respectively. Now these coefficients are passed through the 1-D processor 3 times. Where, *z*-coordinate processor gives the final output as the eight subsets of original image .These coefficients are then stored in external memory in the form of binary file.

For the multiple level of decomposition this binary file can be invoked iteratively to obtain further sublevels.

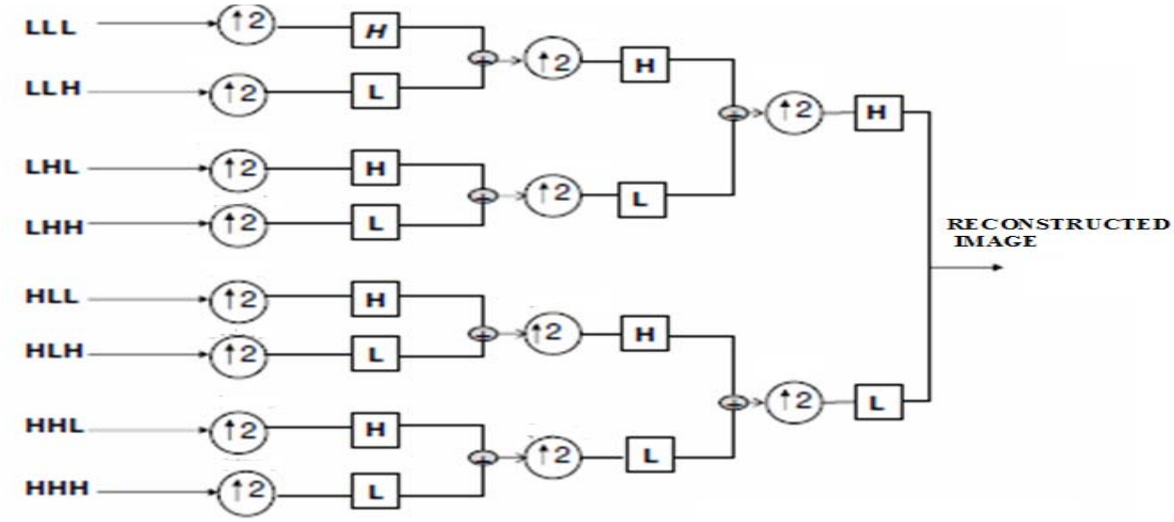

Fig.5. Three-dimensional DWT reconstruction

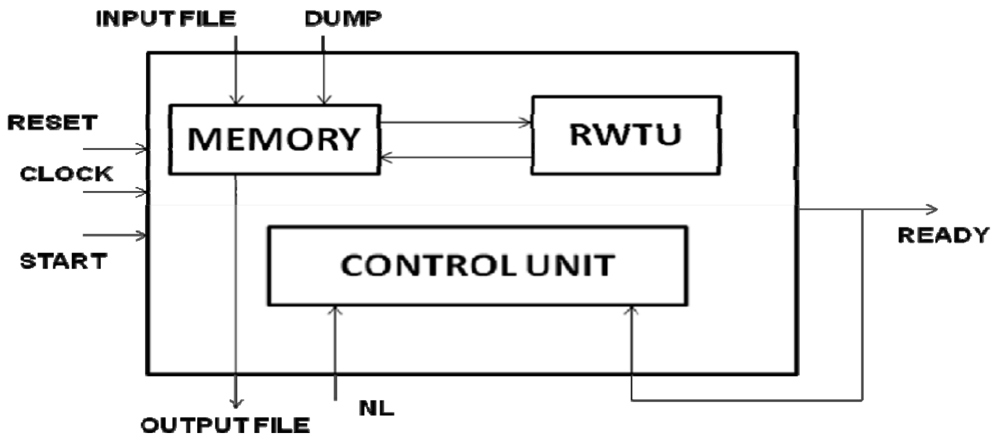

Fig. 6. Architecture of DWT

IV . RESULTS ANALYSIS

TABLE I : SYNTHESIS REPORT

For Forward and Inverse DWT Xilinx Virtex-III FPGA	
No. of Logic Devices Used/ Performance	Figure
FSMs	2
Adders	6
Shifters	2
Registers	93
Tristate buffer	1
Comparators	4
Multiplexers	3
Frequency	85.6MHz
Delay	4.217ns
Memory Size	76.41 MB

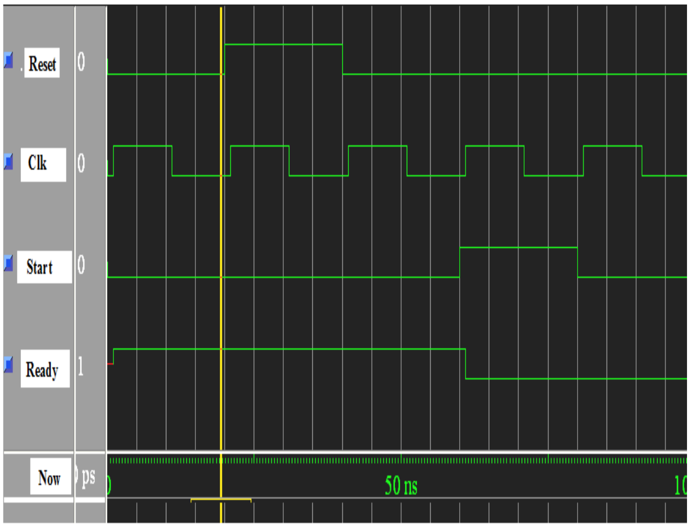

Fig. 7. Simulation Result of 3D DWT

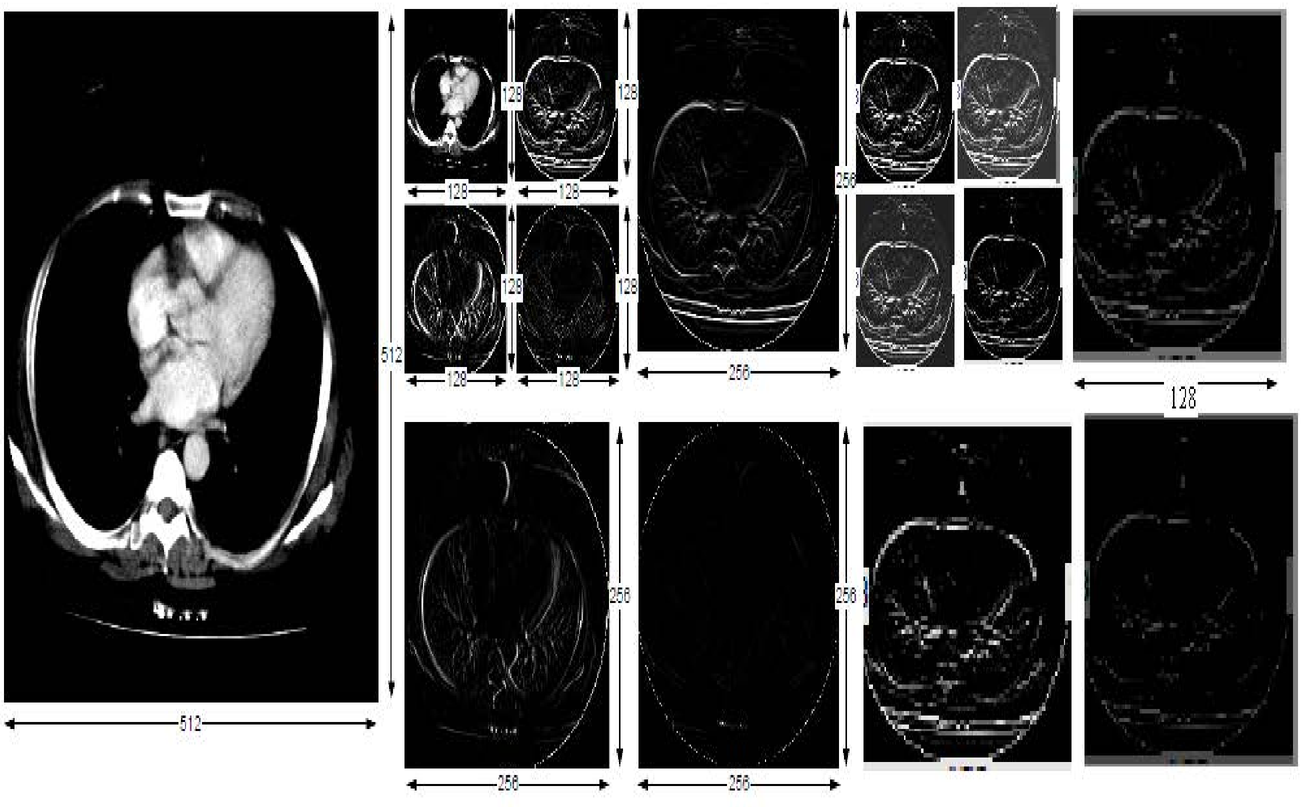

Fig.8. 3D DWT OF A MRA(Magnetic Resonance Angiography) IMAGE

V. CONCLUSION

In conclusion, the proposed lifting based 3D DWT architecture can save hardware cost while being capable of high throughput. This 3D DWT processor makes it possible to map sub filters onto one Xilinx FPGA. Such a high speed processing ability is expected to offer potential for real-time 3D imaging.

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