An Efficient Lifting based 3-D Discrete Wavelet Transform

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ABSTRACT

The digital data can be transformed using Discrete Wavelet Transform (DWT). The Discrete Wavelet Transform (DWT) was based on time-scale representation, which provides efficient multi-resolution. The lifting based scheme (9, 7) (Here 9 Low Pass filter coefficients and the 7 High Pass filter coefficients) filter give lossy mode of information. The lifting based DWT are lower computational complexity and reduced memory requirements. Since Conventional convolution based DWT is area and power hungry which can be overcome by using the lifting based scheme.

The discrete wavelet transform (DWT) is being increasingly used for image coding. This is due to the fact that DWT supports features like progressive image transmission (by quality, by resolution), ease of transformed image manipulation, region of interest coding, etc. DWT has traditionally been implemented by convolution. Such an implementation demands both a large number of computations and a large storage features that are not desirable for either high-speed or low-power applications. Recently, a lifting-based scheme that often requires far fewer computations has been proposed for the DWT.

Keywords – Lifting based scheme, Filter Co-efficient, Multi Resolution Analysis (MRA).

1. INTRODUCTION

The fundamental idea behind wavelets is to analyze according to scale. Indeed, some researchers in the wavelet field feel that, by using wavelets, one is adopting a perspective in processing data. Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. This idea is not new. Approximation using superposition of functions has existed since the early 1800's, when Joseph Fourier discovered that he could superpose sines and cosines to represent other functions. However, in wavelet analysis, the scale that we use to look at data plays a special role.
Wavelet algorithms process data at different scales or resolutions.

Fourier Transform (FT) with its fast algorithms (FFT) is an important tool for analysis and processing of many natural signals. FT has certain limitations to characterize many natural signals, which are non-stationary (e.g. speech). Though a time varying, overlapping window based FT namely STFT (Short Time FT) is well known for speech processing applications, a time-scale based Wavelet

Transform is a powerful mathematical tool for non-stationary signals.

Wavelet Transform uses a set of damped oscillating functions known as wavelet basis. WT in its continuous (analog) form is represented as CWT. CWT with various deterministic or non-deterministic basis is a more effective representation of signals for analysis as well as characterization. Continuous wavelet transform is powerful in singularity detection. A discrete and fast implementation of CWT (generally with real valued basis) is known as the standard DWT (Discrete Wavelet Transform).With standard DWT, signal has a same data size in transform domain and therefore it is a non-redundant transform. A very important property was Multi-resolution Analysis (MRA) allows DWT to view and process.

Fourier transform based spectral analysis is the dominant analytical tool for frequency domain analysis. However, Fourier transform cannot provide any information of the spectrum changes with respect to time. Fourier transform assumes the signal is stationary, but PD signal is always non-stationary. To overcome this deficiency, a modified method-short time Fourier transform allows representing the signal in both time and frequency domain through time windowing functions. The window length determines a constant time and frequency resolution. Thus, a shorter time windowing is used in order to capture the transient behavior of a signal; we sacrifice the frequency resolution. The nature of the real PD signals is non-periodic and transient as shown in such signals cannot easily be analyzed by conventional transforms. So, an alternative mathematical tool- wavelet transform must be selected to extract the relevant time-amplitude information from a signal. In the meantime, we can improve the signal to noise ratio based on prior knowledge of the signal characteristics.

2. LIFTING IMPLEMENTATION OF THE DISCRETE WAVELET TRANSFORM

As the DWT intrinsically constitutes a pair of filtering operations, a unified representation of the poly-phase matrix is introduced as follows[16]:

$$P(z) = \prod_{i=1}^{m} \begin{pmatrix} h_e(z) & g_e(z) \\ h_o(z) & g_o(z) \end{pmatrix}$$

where $h(z)$ and $g(z)$ stand for the transfer functions for the low pass and high pass filter banks, respectively, and all suffixes e and o in the literature correspond to even and odd terms, respectively. Thus, the transform is symbolized with the equation

$$\begin{pmatrix} \lambda(z) & \gamma(z) \end{pmatrix} = \begin{pmatrix} x_e(z) & z^{-1}x_o(z) \end{pmatrix} P(z)$$

$$P(z) = \begin{pmatrix} 1 & \alpha(1+z^{-1}) \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ \beta(1+z) & 1 \end{pmatrix} \begin{pmatrix} 1 & \gamma(1+z^{-1}) \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ \delta(1+z) & 1 \end{pmatrix} \begin{pmatrix} \zeta & 0 \\ 0 & (1/\zeta) \end{pmatrix}.$$

with $\lambda(z)$ and $\gamma(z)$ signifying the filtered low pass and high pass parts of the input $x(z)$.

The lifting scheme [16] factorizes the poly phase representation into a cascade of upper and lower triangular matrices and a scaling matrix which subsequently return a set of linear algebraic equations in the time domain bringing forth the possibility of a pipelined processor.

For instance, the common Daubechies (9, 7) filter bank can be factorized as

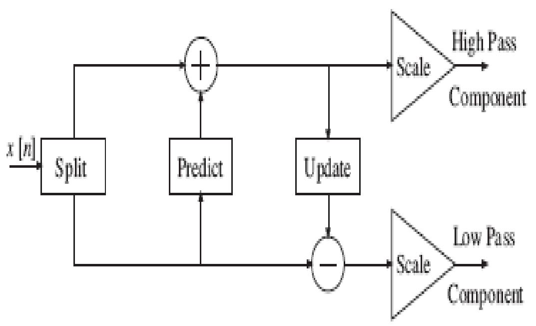

Figure. 1 The lifting scheme: Split, Predict, Update and Scale phases

The related algebraic equations are

$$s_i^0 = x_{2i} \qquad \text{(Splitting)}$$
$$d_i^0 = x_{2i+1}$$
$$d_i^1 = d_i^0 + \alpha \times (s_i^0 + s_{i+1}^0) \qquad \text{(Predict P1)}$$
$$s_i^1 = s_i^0 + \beta \times (d_{i-1}^1 + d_i^1) \qquad \text{(Update U1)}$$
$$d_i^2 = d_i^1 + \gamma \times (s_i^1 + s_{i+1}^1) \qquad \text{(Predict P2)}$$
$$s_i^2 = s_i^1 + \delta \times (d_{i-1}^2 + d_i^2) \qquad \text{(Update U2)}$$
$$s_i = \zeta \times s_i^2 \qquad \text{(Scaling S1)}$$
$$d_i = (1/\zeta) \times d_i^2 \qquad \text{(Scaling S2)}$$

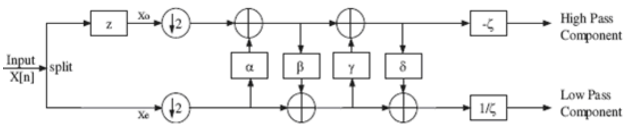

Figure .2 1-D lifting Scheme of daubechies 9/7 for forward wavelet DWT

3. 3-D (9, 7) DWT

The analysis and the synthesis filter coefficients (both low pass and high pass) for Wavelet Transform are as shown in the Table.1.

Table.1

Irrational and rational lifting coefficients for 9/7 wavelet transform

	Irrational value	Rational value
α	$-1.5861343420\ldots$	$-3/2$
β	$-0.0529801185\ldots$	$-1/16$
γ	$0.8828110755\ldots$	$4/5$
δ	$0.4435068520\ldots$	$15/32$
ζ	$1.1496043988\ldots$	$4\sqrt{2}/5$

The rational coefficients allow the transform to be invertible with finite precision analysis, hence giving a chance for performing lossy compression. Initially the Pixel values of any image will be taken with the help of MATLAB, which will be used as the primary inputs to the DWT Block.

Basically 1-D (9, 7) DWT block diagram is developed based on the equations. The registers in the top half will operate in even clock where as the ones in bottom half work in odd clock.

The input pixels arrive serially row-wise at one pixel per clock cycle and it will get split into even and odd. So after the manipulation with the lifting coefficients 'a','b','c' and 'd' is done, the low pass and high pass coefficients will be given out. Hence for every pair of pixel values, one high pass and one low pass coefficients will be given as output respectively.

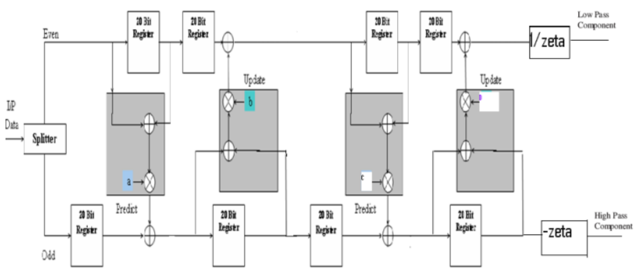

Figure.3 Computation of Basic (9,7) DWT Block in which 'coefficients 'a','b','c' and 'd' are lifting coefficients

The internal operation of the DWT block has been explained above and hence the high pass and low pass coefficients of the taken image were identified and separated. The generated[10] low pass and high pass coefficients are stored in buffers for further calculations.

4. RESULTS

The test bench is developed in order to test the modeled design. This developed test bench will automatically force the inputs and will make the operations of algorithm to perform.

The initial block of the design is that the Discrete Wavelet Transform (DWT) block which is mainly used for the transformation of the image. In this process, the image will be transformed and hence the high pass coefficients and the low pass coefficients were generated. Since the operation of this DWT block has been discussed in the previous chapter, here the snapshots of the simulation results were directly taken in to consideration and discussed.

The input is 16 bits each input bit width is vary because of the multiplier. The DWT consists of registers and adders. When ever the input is send, the data divided into even data and odd data. The even data and odd data is stored in the temporary registers. When the reset is high the temporary register value consists of zero when ever the reset is low the input data split into the even data and odd data. The input data read up to sixteen clock cycles after that the data read according to the lifting scheme. The output data consists of low pass and high pass elements. This is the 1-D discrete wavelet transform. The 2-D discrete wavelet transform is that the low pass and the high pass again divided into LL, LH and HH, HL. The 3-D discrete wavelet transform is that the low pass and the high pass again divided into LLL, LLH, LHL, LHH, HLL, HLH, HHL, and HHH. The output is verified in the Modelsim.

For this DWT block, the clock and reset were the primary inputs. The pixel values of the image, that is, the input data will be given to this block and hence these values will be split in to even and odd pixel values. In the design, this even and odd were taken as a array which will store its pixel values in it and once all the input pixel values over, then load will be made high which represents that the system is ready for the further process.

Simulation Results of top module:

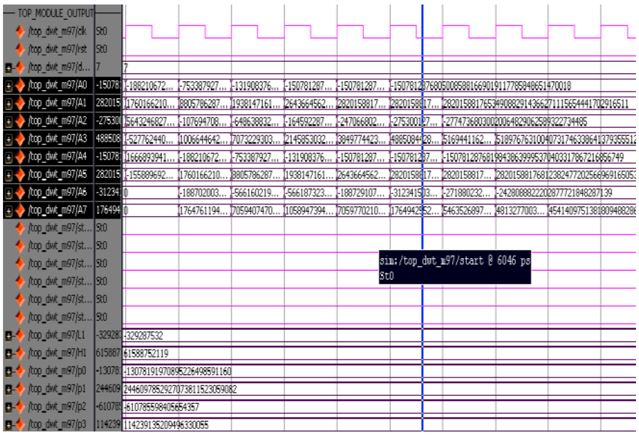

Figure .1 Simulation Result of 3D-DWT(TOP MODULE) Block with High and Low Pass Coefficients LLL, LLH, LHL, LHH, HLL, HLH, HHL and HHH.

Once the load signal is set to high, then the each value from the even and odd array will be taken and used for the Low Pass Coefficients generation process. Hence each value will be given to the adder and in turn given to the multiplication process with the filter coefficients. Finally the Low Pass Coefficients will be achieved from the addition process of multiplied output and the odd pixel value.

Again this Low Pass Coefficient will be taken and it will be multiplied with the filter coefficients. The resultant will be added with the even pixel value which gives the High Pass Coefficient. Hence all the values from even and odd array will be taken and then above said process will be carried out in order to achieve the High and Low Pass Coefficients of the image.

Now these low pass coefficients and the high pass coefficients were taken as the input for the further process. Hence for the DWT-2 process, low pass coefficients will be taken as the inputs and will do the process in order to calculate the low pass and high pass coefficients from the transformed coefficients of DWT-1. In DWT-2, the same process as in DWT-1 will be carried out. Hence the simulated waveform is shown in the figure.1. Similarly the high pass coefficients from the DWT-1 block were taken as input to the DWT-3 block and hence further transformed low pass and high pass coefficients will be obtained. Similarly the process is continued for DWT-4, DWT-5, DWT-6, and DWT-7.

HDL Synthesis Report

Final Results

RTL Top Level Output File Name : top_dwt_m97.ngr

Top Level Output File Name : top_dwt_m97

Output Format : NGC

Optimization Goal : Speed

Keep Hierarchy : NO

Design Statistics

 # IOs : 1612

Cell Usage :

 # BELS : 54288

 # GND : 1

 # INV : 30

 # LUT1 : 1022

 # LUT2 : 17056

 # LUT3 : 133

 # LUT4 : 38

 # LUT5 : 4

 # LUT6 : 8

 # MUXCY : 18001

 # VCC : 1

 # XORCY : 17994

 # FlipFlops/Latches : 14166

 # FDR : 14070

 # FDRE : 83

 # FDSE : 7

 # FDSE_1 : 6

 # RAMS : 46

 # RAM32M : 2

 # RAM32X1D : 8

 # RAMB18 : 8

 # RAMB36_EXP : 24

 # RAMB36SDP_EXP : 4

 # Clock Buffers : 2

 # BUFG : 1

 # BUFGP : 1

 # IO Buffers : 1611

 # IBUF : 11

 # OBUF : 1600

 # DSPs : 670

 # DSP48E : 670

Device utilization summary:

Selected Device : 5vfx200tff1738-1

Slice Logic Utilization:

Number of Slice Registers: 14166 out of 122880 11%

Number of Slice LUTs: 18315 out of 122880 14%

Number used as Logic: 18291 out of 122880 14%

Number used as Memory: 24 out of 36480 0%

Number used as RAM: 24

Slice Logic Distribution:

Number of LUT Flip Flop pairs used: 27459

Number with an unused Flip Flop: 13293 out of 27459 48%

Number with an unused LUT: 9144 out of 27459 33%

Number of fully used LUT-FF pairs: 5022 out of 27459 18%

Number of unique control sets: 42

IO Utilization:

Number of IOs : 1612

Number of bonded IOBs: 1612 out of 960 167% (*)

Specific Feature Utilization:

Number of Block RAM/FIFO: 32 out of 456 7%

Number using Block RAM only: 32

Number of BUFG/BUFGCTRLs: 2 out of 32 6%

Number of DSP48Es: 670 out of 384 174% (*)

5. CONCLUSION

Basically the medical images need more accuracy without loosing of information. The Discrete Wavelet Transform (DWT) was based on time-scale representation, which provides efficient multi-resolution. The lifting based scheme (9, 7) (The high pass filter has five taps and the low pass filter has three taps) filter give lossless mode of information. A more efficient approach to lossless whose coefficients are exactly represented by finite precision numbers allows for truly lossless encoding.

This work ensures that the image pixel values given to the DWT process which gives the high pass and low pass coefficients of the input image. The simulation results of DWT were verified with the appropriate test cases. Once the functional verification is done.

6. FUTURE SCOPE

This work can be extended in order to increase the accuracy by increasing the level of transformations. This can be used as a part of the block in the full fledged application, i.e., by using these DWT, the applications can be developed such as compression, watermarking, etc.

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