

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 7, July 2018

Review Paper on 9/7 Wavelet Filter Coefficient based Discrete Wavelet Transform

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ABSTRACT: Discrete wavelet transform provides an efficient computing method for sparse representation of wide class of signals. The DWT only analyzes the lower frequency sub bands implicitly ignoring any information embedded in the higher frequency sub bands. There are few applications where signal information is equally distributed in the entire signal spectrum.

In this paper, a high speed and area efficient 1-D discrete wavelet transform (DWT) using 9/7 filter based distributed arithmetic (DA) technique is described. Being an area efficient architecture free of ROM, multiplication, and subtraction, DA can also expose the redundancy existing in the adder array consisting of entries of 0 and 1.

KEYWORDS: - 1-D Discrete Wavelet Transform (DWT), DA Technique, Low Pass Filter, High Pass Filter, Xilinx Simulation.

I. INTRODUCTION

A fundamental problem in signal processing is to find a suitable representation for a signal. Images are nonstationary signals. Fourier representation of the signal is well localized in frequency but not in time. In order to represent the signal in time as well as frequency simultaneously, the Short Time Fourier Transformation (STFT) was developed by Dennis Gabor in 1946, where the original signal is multiplied by a window function (e.g. a Gaussian function) and Fourier transform is computed on this modified signal. The STFT analyses a small section of the signal at a time. The problem with STFT is the constant window size, which is difficult to choose. STFT is widely used for analysis of speech signals.

Although wavelet transforms with many different sets of basic functions are possible, orthogonal transforms with symmetric finitely supported basis functions are ideally desirable for image compression. Orthogonality ensures that transform coefficients do not become unreasonably large and it facilitates the selection of the most important transform coefficients in the sense of minimizing mean squared error. Symmetric basis functions ensure no undesirable phase distortion as a result of compression. If phase is not preserved, edges and lines can become severely distorted, resulting in poor subjective image quality. In the case of 2-D wavelet transforms on images, orthogonality, symmetry and finite support can only be achieved in the trivial case of the Haar and other Haar-like transforms.

Discrete wavelet transform (DWT) is a mathematical tool that provides a new method for signal processing and decomposes a discrete signal in the time domain by using dilated / contracted and translated versions of a single basis function, named as prototype wavelet. DWT offers a wide variety of useful features over other unitary transforms like discrete Fourier transforms (DFT), discrete cosine transform (DCT) and discrete sine transform (DST). Some of these features are; adaptive time-frequency windows, lower aliasing distortion for signal processing applications, efficient computational complexity and inherent scalability. Due to these features one dimensional (1-D) DWT and two dimensional (2-D) DWT are applied in various applications such as numerical analysis, signal analysis, image coding, pattern recognition, statistics and biomedicine.

DWT provides an efficient computing method for sparse representation of a wide class of signals. The DWT only analyzes the lower frequency sub-bands, implicitly ignoring any information embedded in the higher frequency

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components. In other word, DWT puts more emphasis on the low frequencies by continuously decomposing the signal in the low-frequency band.

II. DISTRIBUTED ARITHMETRIC (DA)

Let us consider the following sum of products [4]:

$$R = \sum_{k=1}^L X_k \times Y_k \quad (1)$$

Where X_k are fixed coefficients and they Y_k are the input data words. Equation (1) can be expressed in the form of a matrix product as:

$$R = [X_1 \quad X_2 \quad \dots \quad X_L] \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_L \end{bmatrix} \quad (2)$$

Both X_k and Y_k are in two's complement format. The two's complement representation of X_k may be expressed as

$$X_k = -X_k^M 2^M + \sum_{i=N}^{M-1} X_k^i 2^i \quad (3)$$

Where $X_k^i = 0$ or 1, and $i = N, N+1 \dots M$ and X_k^M is the sign bit and X_k^N is the least significant bit (LSB). Equation (3) can be expressed in matrix form as:

$$X_k = \begin{bmatrix} 2^N & 2^{N+1} & \dots & 2^M \end{bmatrix} \begin{bmatrix} X_k^N \\ X_k^{N+1} \\ \vdots \\ -X_k^M \end{bmatrix} \quad (4)$$

Similarly Y_k can be represented in two's complemented format as:

$$Y_k = -Y_k^X 2^X + \sum_{i=W}^{X-1} Y_k^i 2^i \quad (5)$$

Where $Y_k^i = 0$ or 1, and $i = W, W+1, X$ and Y_k^M is the sign bit and Y_k^N is the least significant bit (LSB).

Now on combining equations (1) and (3), we get-

$$R = -(R^M \cdot 2^M) + \sum_{i=N}^{M-1} (R^i \cdot 2^i) \quad (6)$$

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Where

$$R^i = \sum_{k=1}^L X_k^i Y_k, i = N, N+1 \dots M$$

Example of DA Technique

In this paper, we have high speed area efficient multiplier-less 1-D 9/7 wavelet filters based DA technique. 9/7 wavelet filters coefficient i.e. 9 low-pass and 7 high-pass wavelet filters coefficient are given in table1. multiplying the filter coefficients by 128 for simplification. The mathematical calculation for 1-D high pass filter output is explained by an example.

Table 1: present the high-pass and low-pass wavelet filters coefficient.

	Wavelet filters coefficients	Multiplied by 128	7 bit binary representation
h_0	0.60294901823	77	1001101
h_1	0.26686441184	34	0100010
h_2	0.07822326652	10	0001010
h_3	0.01686411844	2	0000010
h_4	0.026748757410	3	0000011
g_0	0.55754352622	71	1000111
g_1	0.29563588155	38	0100110
g_2	0.02877176311	4	0000100
g_3	0.045635881557	6	0000110

In above table h_0, h_1, h_2, h_3, h_4 are Low pass filter coefficients and g_0, g_1, g_2, g_3 are High pass filter coefficients.

When high pass coefficients g_0, g_1, g_2 and g_3 multiply by r_1, r_2, r_3 and r_4 then the product of High pass output Y_H of the 9/7 filter as [6]:

$$Y_H = \begin{bmatrix} g_0 & g_1 & g_2 & g_3 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{bmatrix} \quad (7)$$

Where

$$r_1 = Y(n) + Y(n-6)$$

$$r_2 = Y(n-1) + Y(n-5)$$

$$r_3 = Y(n-2) + Y(n-4)$$

$$r_4 = Y(n-3)$$

Let $r_1=1, r_2=2, r_3=3, r_4=4$ then

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$$Y_H = \begin{bmatrix} 71 & 38 & 4 & 6 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} = 183 \quad (8)$$

Now if implement this with DA then

$$Y_H = \begin{bmatrix} 1000111 & 0100110 & 0000100 & 0000110 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{bmatrix} \quad (9)$$

Now the DA matrix can make by the filter coefficients as

$$[B_k] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \quad (10)$$

$$Y_H = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \end{bmatrix} = \begin{bmatrix} r_1 \\ r_1 + r_2 + r_4 \\ r_1 + r_2 + r_3 + r_4 \\ 0 \\ 0 \\ r_2 \\ r_1 \end{bmatrix} \quad (11)$$

In Figure 1, apply DA techniques as

Step-1

All the input converts' binary number.

Step-2

All the binary input applied to an adder array so.

$$\begin{aligned} P_1 &= 0001, & P_2 &= 0111 \\ P_3 &= 1010, & P_4 &= 0000 \\ P_5 &= 0000, & P_6 &= 0010 \\ P_7 &= 0001 \end{aligned}$$

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The entire adder array input applied to MUX so, the entire adder array input $m(1)$

$$\text{MUX (1)} = 0001 = Y_P(0)$$

$$\begin{aligned} \text{MUX (1) add MUX (2)} &= Y_P(1) \\ &= 00001 \\ &= 01110 \\ &+ 01111 \end{aligned}$$

$$\begin{aligned} \text{Output of the } Y_P(1) \text{ again right shift 1-bit and adds MUX (3) so} \\ &= 001111 \\ &= 101000 \\ &+ 110111 \end{aligned}$$

$$Y_P(1) + \text{MUX (3)} = Y_P(2)$$

$$\begin{aligned} \text{Output of the } Y_P(2) \text{ again right shift 1-bit and adds MUX (6) so} \\ &= 000110111 \\ &= 001000000 \\ &+ 001110111 \\ Y_P(2) + \text{MUX (6)} &= Y_P(3) \end{aligned}$$

Output of the $Y_P(3)$ again right shift 1-bit and adds MUX (7)
So

$$\begin{aligned} &= 001110111 \\ &= 001000000 \\ &+ 010110111 \end{aligned}$$

$$Y_P(3) + \text{MUX (6)} = Y_P(4)$$

$$\text{Total output } Y_P(4) = 010110111 = 183$$

III. VLSI SYSTEM

DWT algorithms can be implemented in a programmable system such as general purpose computer or digital signal processor. These programmable systems use a fixed computing architecture and perform arithmetic operations sequentially and they offer limited throughput for computationally intensive algorithms such as DWT. However, DWT algorithms can be implemented general purpose programmable systems for high-throughput applications employing parallel processing. Engaging general purpose programmable system to perform a specific task is not cost-effective. Besides, general purpose computing systems occupy substantial amount of space and consumes power which makes the deployment of signal processing system difficult in a resource constrained and hostile environment. In recent years, there is tremendous growth of portable and wireless devices in various applications. Portable and wireless devices are resource and power constrained, and uses complex signal processing algorithms including DWT. Besides, high-throughput rate, low-area and low-power are considered the key requirements of systems implementing digital signal processing algorithms especially for portable and wireless devices which are battery operated. Therefore, realization of DWT in resource and power constrained environment and delivering real-time performance is a challenging task for portable and wireless devices.

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IV. CONCLUSION

In this paper studied of distributed arithmetic paradigm named DA for VLSI implementation of digital signal processing (DSP) algorithms involving inner product of vectors and vector-matrix multiplication. Mathematical proof is given for the validity of the DA scheme. The DA is a very efficient architecture with adders as the main component and free of ROM (free memory), multiplication, and subtraction. For the adder array, a systematic approach is introduced in this paper to remove the potential redundancy so that minimum additions are necessary. DA is an accuracy preserving scheme and capable of maintaining a satisfactory performance even at low DA precision.

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