International Journal of Engineering Research and Science & Technology

IJERST

ISSN : 2319-5991
Vol. 4, No. 3
August 2015

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

Int. J. Engg. Res. & Sci. & Tech. 2015

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 4, No. 3, August 2015

Research Paper

DESIGN AND VERIFICATION OF DWT ALGORITHM FOR IMAGE COMPRESSION USING VERILOG

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Image compression is one of the major image processing techniques. Discrete Wavelet Transforms is the most popular transformation technique adopted for image compression. Image compression is the application of Data compression on digital images. A fundamental shift in the image compression approach came after the Discrete Wavelet Transform (DWT) became popular. The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the Internet or downloaded from web pages. JPEG and JPEG 2000 are two important techniques used for image compression. To overcome the inefficiencies in the JPEG standard and serve emerging areas of mobile and internet communications, the new JPEG2000 standard has been developed based on the principles of DWT. This Paper presents an approach towards HDL implementation of the Discrete Wavelet Transform (DWT) for image compression. The design follows the JPEG2000 standard and can be used for both lossy and lossless compression. In order to reduce complexities of the design linear algebra view of DWT has been used in this concept. The design has been developed in Verilog using Altera's Quartus II 9.1 Web Edition.

Keywords: Matlab DWT, Wavelet, Image comprssion, Algorithm

INTRODUCTION

Data compression is the technique to reduce the redundancies in data representation in order to decrease data storage requirements and hence communication costs. Reducing the storage requirement is equivalent to increasing the capacity of the storage medium and hence communication bandwidth. Thus the development of efficient compression techniques will continue to be a design challenge for future communication systems and advanced multimedia applications.

Data is represented as a combination of information and redundancy. Information is the portion of data that must be preserved

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permanently in its original form in order to correctly interpret the meaning or purpose of the data. Redundancy is that portion of data that can be removed when it is not needed or can be reinserted to interpret the data when needed. Most often, the redundancy is reinserted in order to generate the original data in its original form. A technique to reduce the redundancy of data is defined as Data compression. The redundancy in data representation is reduced such a way that it can be subsequently reinserted to recover the original data, which is called decompression of the data.

Transform based methods better preserve subjective image quality, and are less sensitive to statistical image property changes both inside a single images and between images. Prediction methods provide higher compression ratios in a much less expensive way. If compressed images are transmitted an important property is insensitivity to transmission channel noise. Transform based techniques are significantly less sensitivity to channel noise. If transform coefficients are corrupted during transmission, the resulting image is spread homogeneously through the image or image part and is not too disturbing.

Applications of data compression are primarily in transmission and storage of information. Image transmission applications are in broadcast television, remote sensing via satellite, military communication via aircraft, radar and sonar, teleconferencing, and computer communications.

LITERATURE SURVEY

VLSI Implementation of Discrete Wavelet Transform (DWT) for Image Compression [1]. In this paper presents an approach towards VLSI implementation of the Discrete Wavelet Transform (DWT) for image compression. The design follows the JPEG2000 standard and can be used for both lossy and lossless compression. This paper focuses on the hardware implementation of discrete wavelet transform, which will provide the transform coefficients for later stage and is one key part of JPEG2000 implementation.Image Compression using wavelet [2]. In this paper different types of wavelet families are introduced and it provides the fundamental of wavelet based image compression. Different types of wavelets are tested for image compression and image quality measurements for different wavelet functions, image contents, compression ratio and resolution are compared. Different wavelets are used for different application.

Wavelets and filter banks: theory and design [3]. In this paper comparison of wavelet transform and STFT (Sort-Time Fourier Transform) to approach to signal analysis. It gives the review perfect reconstruction filter banks which can be used for both discrete wavelet transform and continuous wavelet transform and also derive the necessary and sufficient condition for the existence of a complementary high pass filter that will permit perfect reconstruction.

Image Compression using 2-D Multi-Level Discrete Wavelet Transform (DWT) [4]. Wavelet transform is used to developed compression technique in image compression. In this paper, multiple level 2-D wavelet transform of images, approximation and detail coefficients are obtained. These coefficients are quantized that more important coefficients are represented with higher accuracy and retained coefficients are represented with less accuracy or they are neglected. The qualities of reconstructed images are measured with PSNR value, and compression ratio is calculated using given formula. Generally wavelet performs better compression than other compression methods.

The Discrete Wavelet Transform

The Wavelet Series is just a sampled version of CWT and its computation may consume significant amount of time and resources, depending on the resolution required. The Discrete Wavelet Transform (DWT), which is based on sub-band coding, is found to yield a fast computation of Wavelet Transform. It is easy to implement and reduces the computation time and resources required.

In CWT, the signals are analyzed using a set of basis functions which relate to each other by simple scaling and translation. In the case of DWT, a time-scale representation of the digital signal is obtained using digital filtering techniques. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales.

DWT and Filter Banks

Filters are one of the most widely used signal processing functions. Wavelets can be realized by iteration of filters with rescaling. The resolution of the signal, which is a measure of the amount of detail information in the signal, is determined by the filtering operations, and the scale is determined by up sampling and down sampling (sub sampling) operations.

The DWT is computed by successive low pass and high pass filtering of the discrete time-domain signal. This is called the Mallat algorithm or Mallat-tree decomposition. Its significance is in the manner it connects the continuous time mutiresolution to discrete-time filters. In the figure, the signal is denoted by the sequence x[n], where n is an integer. The low pass filter is denoted by g[n] while the high pass filter is denoted by h[n]. At each level, the high pass filter produces detail information, while the low pass filter associated with scaling function produces coarse approximations.

The reconstruction of the original signal from the wavelet coefficients. Basically, the reconstruction is the reverse process of decomposition. The approximation and detail coefficients at every level are up sampled by two, passed through the low pass and high pass synthesis filters and then added. This process is continued through the same number of levels as in the decomposition process to obtain the original signal.

One Level of the Transform

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

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

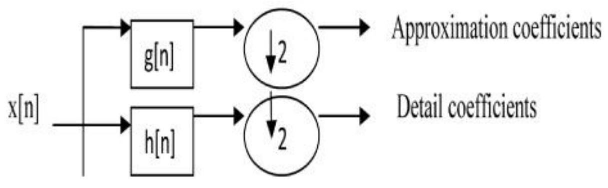
The signal is also decomposed simultaneously using a high-pass filter h. The output giving the detail of coefficients (from the high-pass filter) and approximation coefficients (from the low-pass). It is important that the two filters are related to each other and they are known as a quadrature mirror filter. However, since half the frequencies of the signal have now been removed, half the samples can be discarded according to Nyquist’s rule. The filter outputs are then sub sampled by 2 (Mallat’s and the common notation is the opposite, g- high pass and h-low pass)

$$y_{low}[n] = \sum_{k=\infty}^{-\infty} x[k]g[2n-k]$$

$$y_{high}[n] = \sum_{k=\infty}^{-\infty} x[k]h[2n-k]$$

This decomposition has halved the time resolution since only half of each filter output characterizes the signal. However, each output has half the frequency band of the input so the frequency resolution has been doubled.

Figure 1: One Level of Transform



With the sub sampling operator

$(y \downarrow k)\,[n] = y[kn] \downarrow$

the above summation can be written more concisely.

$$y_{low} = (x * g) \downarrow 2$$

$$y_{high} = (x * h) \downarrow 2$$

However computing a complete convolution $x * g$ with subsequent downsampling would waste computation time.

Multi-Resolution Analysis Using Filter Banks

Filters are one of the most widely used signal processing functions. Wavelets can be realized by iteration of filters with rescaling. The resolution of the signal, which is a measure of the amount of detail information in the signal, is determined by the filtering operations, and the scale is determined by up sampling and down sampling (sub sampling) operations.

The DWT is computed by successive low pass and high pass filtering of the discrete time-domain signal as shown in Figure 2. This is called the Mallat algorithm or Mallat-tree decomposition. Its significance is in the manner it connects the continuous time mutiresolution to discrete-time filters. In the figure, the signal is denoted by the sequence x[n], where n is an integer. The low pass filter is denoted by G0 while the high pass filter is denoted by H0. At each level, the high pass filter produces detail information; d[n], while the low pass filter associated with scaling function produces coarse approximations, a[n].

At each decomposition level, the half band filters produce signals spanning only half the frequency band. This doubles the frequency resolution as the uncertainty in frequency is reduced by half. In accordance with Nyquist's rule if the original signal has a highest frequency of μ, which requires a sampling frequency of 2μ radians, then it now has a highest frequency of μ/2 radians. It can now be sampled at a frequency of μ radians thus discarding half the samples with no loss of information. This decimation by 2

Figure 2: Three-Level Wavelet Decomposition Trees

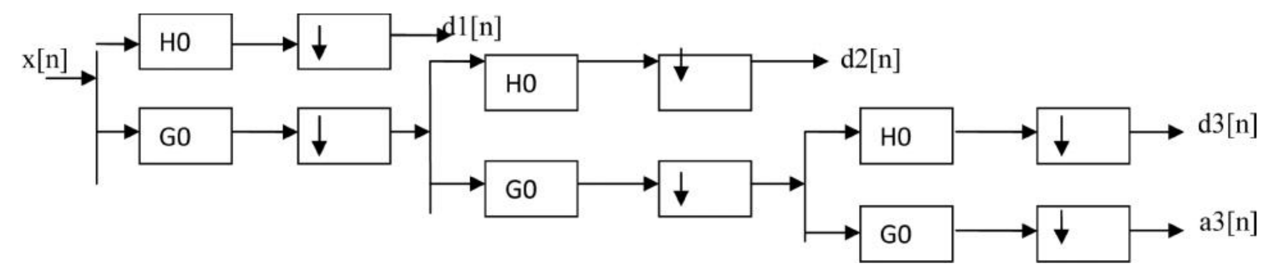
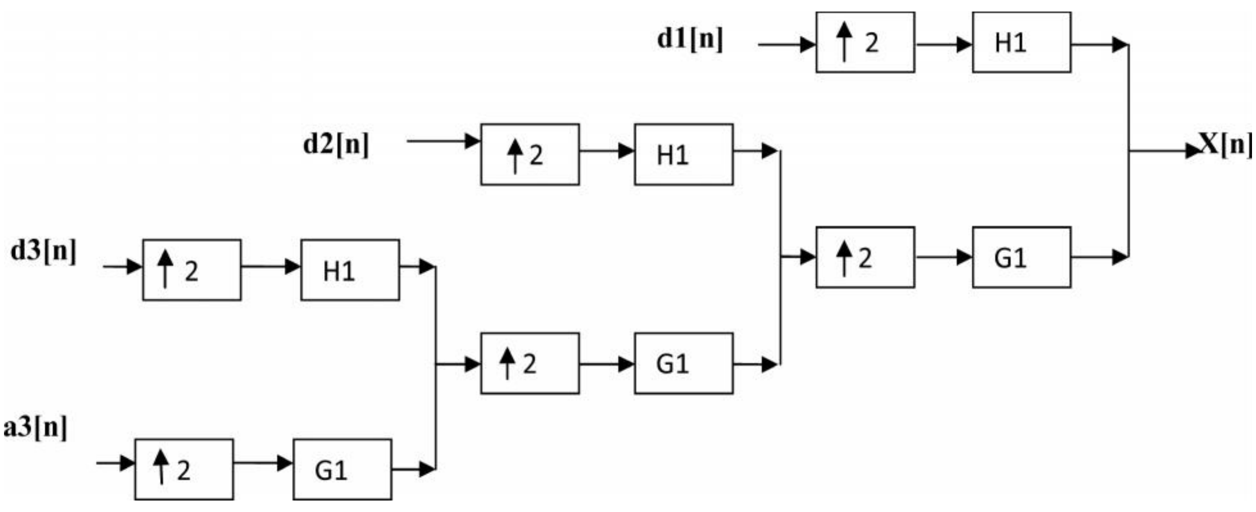


Figure 3: Three-Level Wavelet Reconstruction Tree



halves the time resolution as the entire signal is now represented by only half the number of samples. Thus, while the half band low pass filtering removes half of the frequencies and thus halves the resolution, the decimation by 2 doubles the scale.

With this approach, the time resolution becomes arbitrarily good at high frequencies, while the frequency resolution becomes arbitrarily good at low frequencies. The time-frequency plane is thus resolved. The filtering and decimation process is continued until the desired level is reached. The maximum number of levels depends on the length of the signal. The DWT of the original signal is then obtained by concatenating all the coefficients, a[n] and d[n], starting from the last level of decomposition.

Figure 3 shows the reconstruction of the original signal from the wavelet coefficients. Basically, the reconstruction is the reverse process of decomposition. The approximation and detail coefficients at every level are up sampled by two, passed through the low pass and high pass synthesis filters and then added. This process continued through the same number of levels as in the decomposition process to obtain the original signal. The Mallat algorithm works equally well if the analysis filters, G0 and H0 are exchanged with the synthesis filters, G1 and H1.

RESULTS AND DISCUSSION

Analysis and Synthesis Summary

The analysis and synthesis report of the design is shown below:

Table 1: Flow Summary of Compilation Report

Flow Status	Successful - Thus June 14 10:44:7
Quartus Version	9.0 Build 132 02/25/2009 sj Web Edition
Revision Name	Wavelet
Top level entity	Wavelet
Family	Cyclone II
Device	EP2C70F896C6
Timing Model	Final
Met timing requirements	Yes
Total logic elements	4627/68416 (7%)
Total combinational function	4162/68416 (6%)
Dedicated Logic Registers	676/68416 (< 1%)

Table 1 (Cont.)

Total Registers	676
Total pins	163/622 (26%)
Total virtual pins	0
Total memory bits	0/1152000 (0%)
Embedded multiplier 9-bit element	192/300 (64%)
Total PLL	0/4 (0%)

Simulation

The top level entity consists of low pass, high pass filter, and down sample modules. These sub modules are programmed, synthesized and simulated. Once the programming is completed the tests and simulations were performed on each module to verify the functionality of individual module by using simulator available in Quartus II tool.

Simulation results are shown in figure.

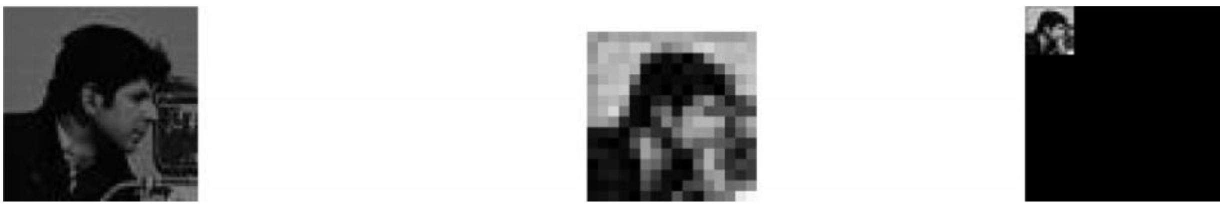
Result

The grayscale cameraman image of 64 x 64 pixels is taken as an input (generated with the help of MATLAB Tool) for the DWT algorithm designed in HDL and is compressed at two levels. After two level compressions, the image is represented by 16 x 16 pixels. The compressed simulated data is in binary format thus to visualize these compressed data image plotting tool of MATLAB is used. Figures 4 and 5 shows the original image and compressed image using HDL simulation and MATLAB tool. The compressed image is basically the LL-2 part of the DWT algorithm. DWT algorithm for image compression can be used at any level of compression.

The DWT algorithm is designed and verified with the help of simulation. This algorithm is designed in verilog HDL so it can be implemented on the hardware. This DWT algorithm gives the compressed result of input image. This result is verified with the help of simulation tool.

Figures 4 and 5 shows the compression of the image data using HDL simulation and MATLAB tool, original image and compressed image are shown in the figure.

Figure 4: Test Image 1-(a) Original Image (b) Compressed Image Using HDL Simulation Tool

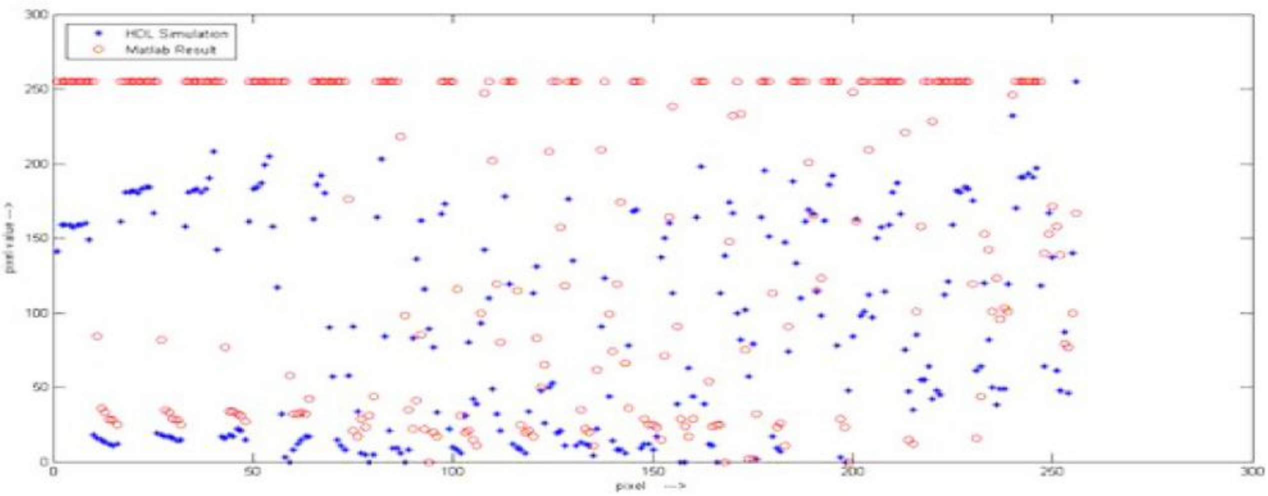


(a) Original Image (b) Compressed Image after Two level DWT

Figure 5: Test Image 1-(a) Original Image (b) Compressed Image Using MATLAB Tool

(a) Original Image (b) Compressed Image after Two level DWT using MATLAB tool

Figure 6: Graph Between HDL Simulation Result and MATLAB Result of Test Image 1



The Graph is plotted using MATLAB tool and results of HDL simulation and MATLAB tool can be analyzed with the help of graph.

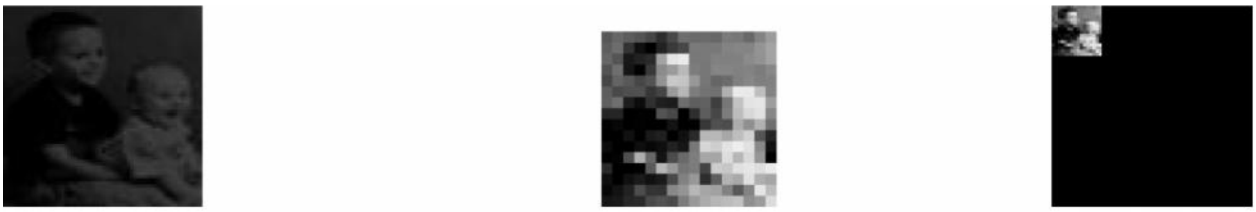
Figure 6 shows the graph of HDL simulation result and MATLAB result of test image 1.

Figures 7 and 8 shows the compression of the image data using HDL simulation and MATLAB tool original image and compressed image are shown in the figure.

The Graph is plotted using MATLAB tool and results of HDL simulation and MATLAB tool can be analyzed with the help of graph.

Figure 9 shows the graph of HDL simulation result and MATLAB result of test image 2.

Figure 7: Test Image 2-(a) Original Image (b) Compressed Image Using HDL Simulation



(a) Original Image

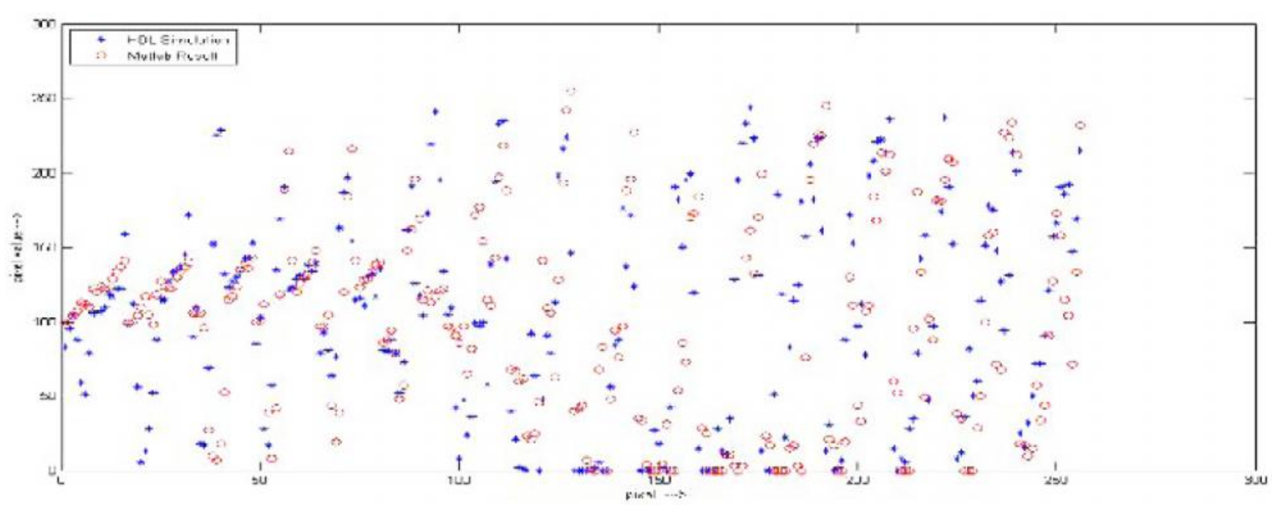
(b) Compressed Image after Two level DWT

Figure 8: Test Image 2-(a) Original Image (b) Compressed Image Using MATLAB Tool

(a) Original Image

(b) Compressed Image after Two level DWT using MATLAB tool

Figure 9: Graph Between HDL Simulation Result and MATLAB Result of Test Image 2



CONCLUSION

DWT algorithm using the Daubechies (db2)-4 tap wavelet is studied and designed in Verilog HDL using Quartus II 9.0 software. Filter based DWT is the simplest, it is selected for hardware implementation.

The 2D-DWT algorithm code was written in the Verilog HDL. It is then synthesized and simulated successfully. Pixels value of input images are taken, and DWT coefficients is calculated through DWT algorithm designed in Verilog HDL and the same images are used for calculating DWT using MATLAB. Image compression with the help of HDL simulation and using MATLAB tool is compared. It is found that the value of DWT is approximately same in both the implementation methodology; however, the intensity of the image compressed with MATLAB tool is higher than that of the HDL simulation. This is due to shifting of the values in HDL coding.

Variable levels of compression can be easily achieved using HDL. The number of DWT stages can be varied, resulting in different number of sub bands. Different filter banks with different characteristics can be used. Efficient fast algorithm (pyramidal computing scheme) for the computation of discrete wavelet coefficients makes a wavelet transform based encoder computationally efficient.

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ISSN 2319-5991