IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 3, Ver. III (May-Jun .2016), PP 42-45
www.iosrjournals.org

VLSI Implementation of Discrete Wavelet Transform (DWT) for Image Compression

Prof. Abhinav V. Deshpande[1]
[1]*Assistant Professor Department of Electronics & Telecommunication Engineering*
Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati-444701

Abstract: *This research paper presents an approach towards VLSI implementation of Discrete Wavelet Transform (DWT) for image compression. The design follows the JPEG 2000 standard and can be used for both lossy and lossless compression. In order to reduce the complexities of the design, linear algebra view of DWT has been used in this research paper. This design can be used for image compression in a robotic system. In this research paper, Discrete Wavelet Transform (DWT) filter bank is presented. The filter bank implemented here is Daubechies 9/7-tap bi-orthogonal filter bank.*
Keywords: *Discrete Wavelet Transform (DWT), image compression, thresholding, VLSI Design, JPEG 2000*

I. Introduction

In today's technological world as our use of and reliance on computers continue to grow, so too does our need for efficient ways of storing large amounts of data and due to the bandwidth and storage limitations, the images must be compressed before transmission and storage. For example, someone with a web page or online catalog that uses dozens or perhaps hundreds of images will be more than likely need to use some form of image compression to store those images [1][2]. This is because the amount of space which is required for holding unadulterated images can be prohibitively large in terms of cost. Fortunately, there are several methods of image compression which are available today. This fall into two general categories: lossless and lossy image compression. However, the compression will reduce the image fidelity, especially when the images are compressed at lower bit rates. The reconstructed images suffer from blocking artifacts and the image quality will be severely degraded under the circumstances of high compression ratios. Image compression is very important for efficient transmission and storage of images [2]. The demand for communication of multimedia data through the telecommunication network and accessing the multimedia data through internet is growing explosively. With the use of digital cameras, the requirements for storage, manipulation and transfer of digital images has grown explosively. These image files can be very large and can occupy a lot of memory. A gray scale image that is 256 x 256 pixels has 65536 elements to store and a typical 640 x 480 color image has nearly a million. The process of downloading of these files from the internet can be very time consuming TASK. The image data comprises of a significant portion of the multimedia data and they occupy the major portion of the communication bandwidth for multimedia communication. Therefore, the development of efficient techniques for image compression has become quite necessary [2][4]. A common characteristic of most of the images is that the neighboring pixels are highly correlated and therefore contain highly redundant information. The basic objective of image compression is to find an image representation in which the pixels are less correlated. The two fundamental principles which are used in image compression are redundancy and irrelevancy [1][3]. The redundancy removes the redundancy from the signal source and irrelevancy omits the pixel values which are not noticeable by the human eye. The JPEG and the JPEG 2000 are the two important techniques which are used for image.

II. The Discrete Wavelet Transform (Dwt)

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 which is 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 which are required [2][5].

The foundations of DWT go back to 1976 when techniques to decompose discrete time signals were devised. Similar work was done in speech signal coding which was named as sub-band coding. In 1983, a technique similar to sub-band coding was developed which was named as pyramidal coding. Later many improvements were made to these coding schemes which resulted in the efficient multi-resolution analysis schemes [1][3]. In CWT, the signals are analyzed by using a set of basic 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 by using digital filtering techniques. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales [4][5].

III. Multi-Resolution Analysis Using Filter Bank

The filters are one of the most widely used signal processing functions. Wavelets can be realized by iterations 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 [2][4].

The DWT is computed by successive low pass and high pass filtering of the discrete time domain signal as shown in the figure. This is called the Mallat algorithm or Mallat-tree decomposition. It's significance is in the manner it connects the continuous-time multi resolution to discrete time filters. In the figure, the signal is denoted by the sequence x(n), where n is any integer [1][4]. The low pass filter is denoted by G_0 while the high pass filter is denoted by H_0. At each level, the high pass filter produces the detailed information, d(n), while the low pass filter which is associated with the scaling function produces coarse approximation a(n) [2][5].

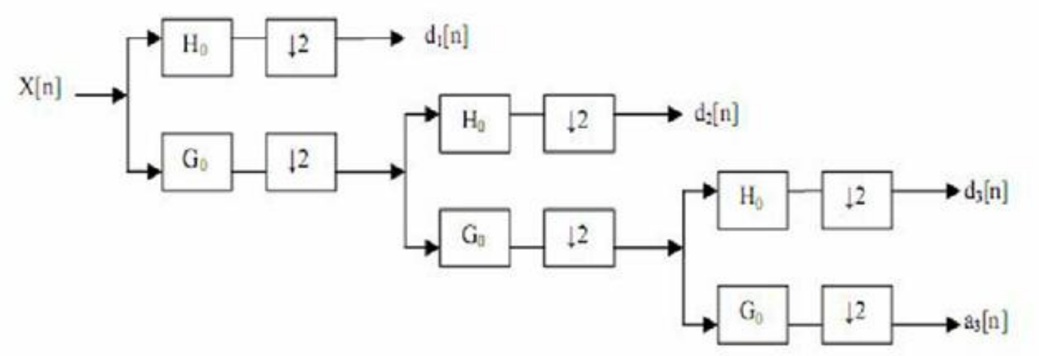

Fig.1 Three Level Wavelet Decomposition Tree

At each decomposition level, the half band filters produce the 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 ω, which requires a sampling frequency of 2ω radians, then it now has a highest frequency of ω/2 radians. It can now be sampled at a frequency of ω radians thus discarding half the samples with no loss of information [3][5]. This decimation by 2 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 [5][6].

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 [1][3]. 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 [2][6].

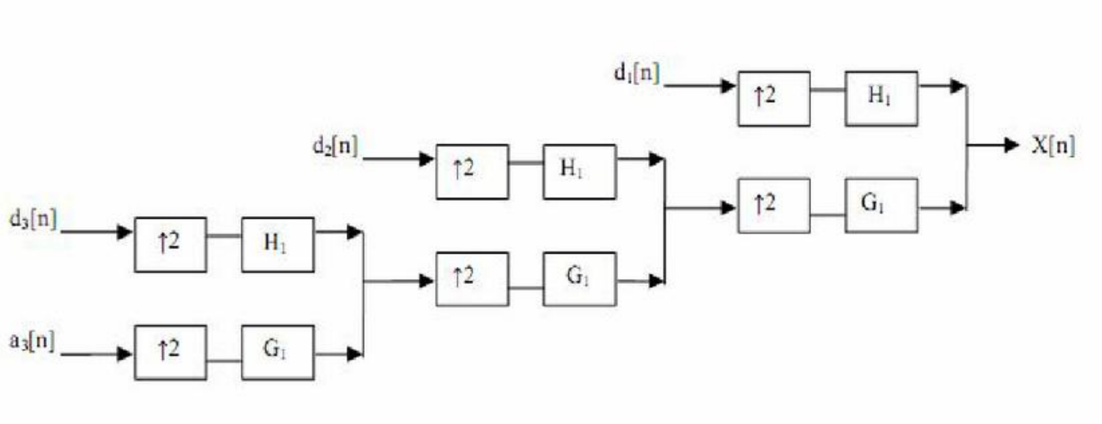

Fig.2 Three Level Wavelet Reconstruction Tree

Figure 2 shows the reconstruction of the original signal from the wavelet coefficients. Basically, the reconstruction is the reverse process of decomposition. The approximation and details coefficients at every level are up sampled by two, passed through the low pass and high pass synthesis filters and then added [4][6]. This process is continued through the same number of levels as in the decomposition process in order to obtain the original signal. The Mallat algorithm works equally well if the analysis filters, G_0 and H_0 are exchanged with the synthesis filters, G_1H_1 [1][3].

IV. Condition For Perfect Reconstruction

In most of the Wavelet Transform applications, it is required that the original signal be synthesized from the wavelet coefficients [2][5]. In order to achieve perfect reconstruction, the analysis and synthesis filters have to satisfy certain conditions. Let $G_0(z)$ and $G_1(z)$ be the low pass analysis and synthesis filters, respectively and $H_0(z)$ and $H_1(z)$ be the high pas analysis and synthesis filters respectively. Then the filters have to satisfy the following two conditions:

$$G_0(-z)G_1(z)+H_0(-z)H_1(z) = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn (1)}$$
$$G_0(z)G_1(z)+H_0(z)H_1(z) = 2z^{-d} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{Eqn (2)}$$

The first condition implies that the reconstruction is aliasing free and the second condition implies that the amplitude distortion has amplitude of one. It can be observed that the perfect reconstruction condition does not change if we switch the analysis and synthesis filters [2][4]. There are a number of filters which satisfy these conditions. But not all of them give accurate wavelet transforms, especially when the filter coefficients are quantized. The accuracy of the wavelet transform can be determined after reconstruction by calculating the Signal to Noise Ration (SNR) of the signal. Some applications like pattern recognition do not need reconstruction and in such applications, the above conditions need not apply [3][6].

V. Conclusion

In this research paper, an improved and efficient Discrete Wavelet Transform (DWT) Algorithm has been developed and tested in MATLAB. Then the algorithm has been modified for implementation in VHDL by using Aldec Active HDL 3.5. From the satisfactory simulation results we can conclude that the algorithm works properly. This VHDL code was also synthesized in order to achieve the gate level architecture of the design which is now ready to be implemented in the hardware. Though I don't have any results of my own work but after studying the different books and different research papers which were presented on this topic, we can conclude that the wavelet analysis is very powerful and extremely useful for compressing data such as image. Although other transforms have been used for example, the DCT was used for the JPEG format in order to compress the images; wavelet analysis can be seen to be far more superior, in that it doesn't create "blocking artifacts". This is because the wavelet analysis is done on the entire image rather than sections at a time. A well known application is the compression of fingerprint images by the FBI. By changing the decomposition level, the amount of detail in the decomposition is changed. Thus, at higher decomposition levels, higher compression rates can be gained. However, more energy of the signal is vulnerable to loss. The wavelet divides the energy of an image into an approximation sub signal, and the detail sub signals. The wavelets that can compact the majority of energy into the approximation sub signal provides the best compression. This is because a large number of coefficients which are contained within the detailed sub signals can be safely set to zero, thus compressing the image. However, a little energy should be lost. The wavelets attempt to approximate how an image I changing, thus the best wavelet to use for an image would be the one that approximates the image well. However, although this report discusses some relevant image properties, there was no time for doing research or investigate how to find the best wavelet to use for a particular image.

Acknowledgments

I am very much thankful to all of the staff members and the Head of Department, Electronics & Telecommunication Engineering, Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati-444701 for their kind support and co-operation in successful carrying out this research work. This research work was undertaken as a part of Technical Education Quality Improvement Program (TEQIP-2) in order to promote and facilitate the current and emerging trends in the field of Electronics & Telecommunication Engineering so that the new and young researchers working in the fields of research and development in Electronics Engineering domain should get the benefit of pursuing their main hobbies which are pertaining to the Embedded Systems platform and should try to learn the new skills and expertise in the particular field of Embedded Systems and Wireless Networks.

References

[1]. K.K. Parhi and T. Nishitani, "VLSI Architectures for Discrete Wavelet Transforms", IEEE Transaction on Very Large Scale Integration (VLSI) Systems, Volume 1, No. 6, pp. 191-202, June 1993.
[2]. C. Chakrabarti, M. Vishwanath and R. M. Owens, "Architectures for Wavelet Transforms: A Survey", Journal of VLSI Signal Process, Volume 14, pp. 171-192, 1996.

[3]. H. Olkkonen, J. T. Olkkonen and P. Pesola, “Efficient Lifting Wavelet Transform for Microprocessor and VLSI Applications”, IEEE Signal Process. Lett., Volume 12, pp. 120-122, 2005.
[4]. P. K. Campbell, K. E. Jones, R. J. Hubber, K. W. Horch and R. A. Normann, “A Silicon-Based Three Dimensional Neural Interface: Manufacturing processes for an intracortical electrode array”, IEEE Transactions on Biomedical Engineering, Volume 38, No. 8, pp. 758-768, August 1991.
[5]. K. D Wise, D. J. Anderson, J. F. Hetke, D. R. Kipke and K. Najafi, “Wireless Implantable Microsystems: High Density Electronic Interfaces to the Nervous System”, Proceedings of IEEE, Volume 92, No. 1, pp. 76-97, January 2004.
[6]. D. M. Taylor, S. I. Tillery and A. B. Schwartz, “Direct Control of 3-D Neuroprosthetic Devices”, Science Volume 296, pp. 1829-1832, 2002.