Image Compression Using Wavelet Transform Based on the Lifting Scheme and its Implementation

A.Alice Blessie[1], J. Nalini[2] and S.C.Ramesh[3]

[1] Applied Electronics, Anna University, PSN College of Engineering & Technology, Tirunelveli, Tamilnadu , India

[2] Electronics And Communication , Anna University , PSN College of Engineering & Technology, Tirunelveli, Tamilnadu, India

[3] Avionics, Anna University , PSN College of Engineering & Technology, Tirunelveli, Tamilnadu, India

Abstract

This paper presents image compression using 9/7 wavelet transform based on the lifting scheme. This is simulated using ISE simulator and implemented in FPGA. The 9/7 wavelet transform performs well for the low frequency components. Implementation in FPGA is since because of its partial reconfiguration. The project mainly aims at retrieving the smooth images without any loss. This design may be used for both lossy and lossless compression.
Keywords: image compression, wavelet transform, implementation

1. Introduction

In many applications, such as image de-noising or compression, transforms are used to obtain a compact representation of the analyzed image. The wavelet transform relies on a set of functions that are translates and dilates of a single ”mother” function, and provides sparse representation of a large class of real-world signals and images.

Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level. 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.

There are several different ways in which image files can be compressed. For Internet use, the two most common compressed graphic image formats are the JPEG format and the GIF format. The JPEG method is more often used for photographs, while the GIF method is commonly used for line art and other images in which geometric shapes are relatively simple.

Other techniques for image compression include the use of fractals and wavelets. These methods have not gained widespread acceptance for use on the Internet as of this writing. However, both methods offer promise because they offer higher compression ratios than the JPEG or GIF methods for some types of images. Another new method that may in time replace the GIF format is the PNG format.

A text file or program can be compressed without the introduction of errors, but only up to a certain extent. This is called lossless compression. Beyond this point, errors are introduced. In text and program files, it is crucial that compression be lossless because a single error can seriously damage the meaning of a text file, or cause a program not to run. In image compression, a small loss in quality is usually not noticeable. There is no "critical point" up to which compression works perfectly, but beyond which it becomes impossible. When there is some tolerance for loss, the compression factor can be greater than it can when there is no loss tolerance. For this reason, graphic images can be compressed more than text files or programs.

In JPEG also there are some limitations. In order to overcome those limitations ISO has come with new standard , which is based on new technology called the wavelet technology[1].

A field programmable gate array (FPGA) contains a matrix of reconfigurable gate array logic circuitry that, when configured, is connected in a way that creates a hardware implementation of a software application. Increasingly sophisticated tools are enabling embedded control system designers to more quickly create and more easily adapt FPGA-based applications. Unlike processors, FPGAs use dedicated hardware for processing logic and do not have an operating system. Because the processing paths are parallel, different operations do not have to compete for the same processing resources. That means speeds can be very fast, and multiple control loops can run on a single FPGA device at different rates. Also, the reconfigurability of FPGAs can provide designers with almost limitless flexibility. In manufacturing and automation contexts, FPGAs are well-suited for use in robotics and machine tool applications, as well as for fan, pump, compressor and conveyor control[2].

2. Proposed Methodology

The smooth variations in images are called the low frequency components where the sharp variations are the high frequency components. The low frequency components forms the base of an image where the high frequency components add upon them to refine the image. Hence the averages or the smooth variations demands more importance than details[3]. Hence performing 9/7 wavelet transform for smooth images gives better results. Lifting scheme is a technique for constructing second generation wavelet transform.

2.1 Discrete Wavelet Transform

"Discrete Wavelet Transform", transforms discrete signal from time domain into time-frequency domain. The transformation product is set of coefficients organized in the way that enables not only spectrum analyses of the signal, but also spectral behavior of the signal in time. This is achieved by decomposing signal, breaking it into two components, each caring information about source signal. Filters from the filter bank used for decomposition come in pairs: low pass and high pass. The filtering is succeeded by down sampling (obtained filtering result is "re-sampled" so that every second coefficient is kept). Low pass filtered signal contains information about slow changing component of the signal, looking very similar to the original signal, only two times shorter in term of number of samples. High pass filtered signal contains information about fast changing component of the signal. In most cases high pass component is not so rich with data offering good property for compression. In some cases, such as audio or video signal, it is possible to discard some of the samples of the high pass component without noticing any significant changes in signal. Filters from the filter bank are called "wavelets".

The other perspective to the same theory is based on the fact that some signals, such as audio or video signals often carry redundant information. For instance, looking at the digital picture reveals that neighboring pixels often differ very slightly. The idea is to find a mathematical relation that connects neighboring data samples (pixels) and reduces their number. Of course, inverse process is needed to reconstruct the original.

The wavelet transform (WT) has gained widespread acceptance in signal processing and image compression. Because of their inherent multi-resolution nature, wavelet-coding schemes are especially suitable for applications where scalability and tolerable degradation are important. Recently the JPEG committee has released its new image coding standard, JPEG-2000, which has been based upon DWT. Wavelet transform decomposes a signal into a set of basis functions. These basis functions are called wavelets.
Wavelets are obtained from a single prototype wavelet y(t) called mother wavelet by dilations and shifting:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \qquad (1)$$

where *a* is the scaling parameter and *b* is the shifting parameter.

2.2 2-D for DWT

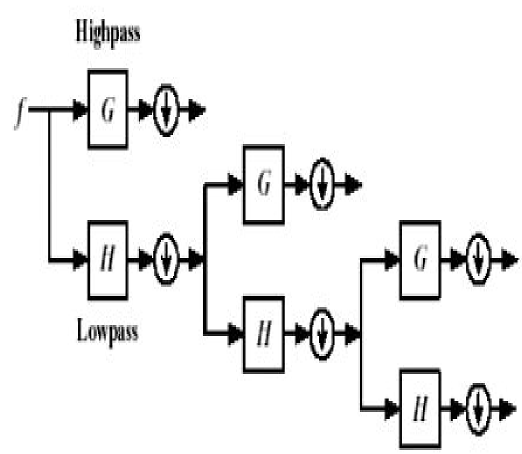

Fig 1. 2-D for discrete wavelet transform

2.3 The Lifting Scheme

The wavelet Lifting Scheme is a method for decomposing wavelet transforms into a set of stages. Lifting scheme algorithms have the advantage that they do not require temporary arrays in the calculations steps and have less computations.We use the lifting coefficients to represent the discrete wavelet transform kernel[4].

2.3.1 Three Steps in lifting scheme

a)Split step

It is also called lazy wavelet transform. It divides the input data into odd and even elements.

b)Predict step
This step predicts the odd elements from the even elements.

c)Update step
This replaces the even elements with an average.

3. Block Diagram

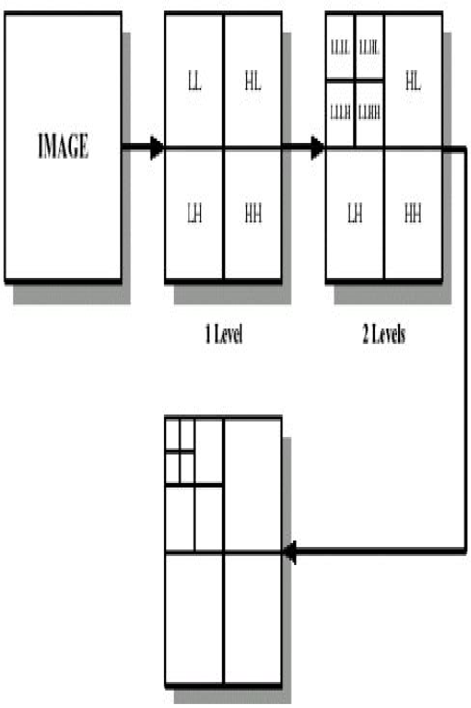

Fig. 2 Block diagram for DWT

3.1 Three stages of waveletting

The 512 by 512 pixel input image frame is processed with three stages of waveletting. In the first stage, 512 pixels of each row are used to compute 256 high pass coefficients (g)and 256 low pass coefficients (ff), figure 3. The coefficients are written back in place of the original row.

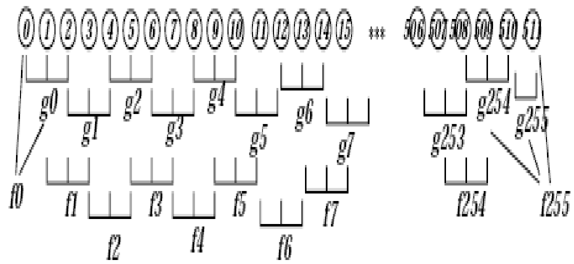

Fig. 3 Waveletting

Once all the 512 rows are processed, the filters are applied in the Y direction. This completes the first stage of wave-letting. While conventional Mallot ordering scheme aggregates coefficients into the 4 quadrants, our ordering scheme interleaves the coefficients in the memory. The second stage of wave-letting only processes the low frequency coefficients from the first stage. This corresponds
to the upper left hand quadrant in the Mallot scheme. Thus, second stage operates on row and columns of length 256, while the third stage operates on rows and columns of length 128. The aggregation of coefficients along the 3 stages under Mallot ordering is shown in figure4. The memory map with the interleaved ordering is shown in figure 5.

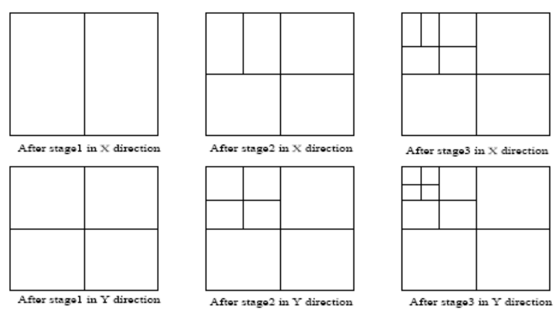

Fig .4 Mallot Ordering

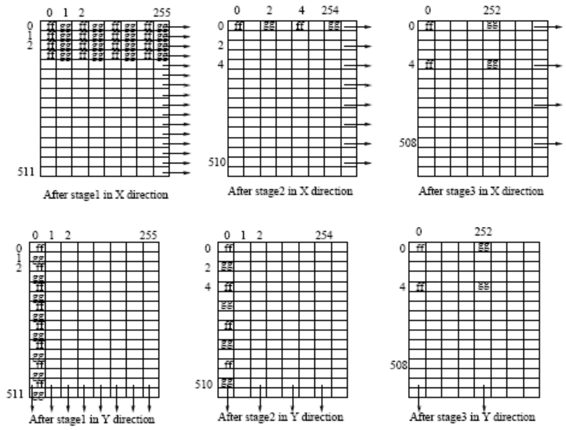

Fig .5 Stages of waveletting

4. Results

Fig. 6 The original image

Fig. 7 The compressed image

$$\text{MSE} = \frac{1}{512x512}\sum_{x=1}^{x=512}\sum_{y=1}^{y=512}[p(x,y)-p'(x,y)]^2 \quad (2)$$

$$\text{RMSE} = \sqrt{MSE} \quad (3)$$

$$\text{PSNR} = 20\log10(255/RMSE) \quad (4)$$

Fig .8 Lena image after 3-level of transform

5. Conclusion

Real time signals are both time-limited (or space limited in the case of images) and band-limited. Time-limited signals can be efficiently represented by a basis of block functions (Dirac delta functions for infinitesimal small blocks). But block functions are not band-limited. Band limited signals on the other hand can be efficiently represented by a Fourier basis. But sines and cosines are not time-limited. Wavelets are localized in both time (space) and frequency (scale) domains. Hence it is easy to capture local features in a signal. Another achievement of a wavelet basis is that it supports multi resolution. In the windowed Fourier transform, the effect of the window is to localize the signal being analyzed. Because a single window is used for all frequencies, the resolution of the analysis is same at all frequencies. To capture signal discontinuities (and spikes), one needs shorter windows, or shorter basis functions. At the same time, to analyze low frequency signal components, one needs longer basis functions. With a wavelet based decomposition, the window sizes vary. Thus it allows to analyze the signal at different resolution levels.

Computationally intensive problems often require a hardware intensive solution. Unlike a microprocessor with a single MAC unit, a hardware implementation achieves greater parallelism, and hence higher throughput. Reconfigurable hardware is best suited for rapid prototyping applications where the lead time for implementation can be critical. It is an ideal development environment, since bugs can be fixed and multiple design iterations can be done, without incurring any non recurring engineering costs. Reconfigurable hardware is also suited for applications with rapidly changing requirements. In effect, the same piece of silicon can be reused. With respect to limitations, achieving good timing/area performance on these FPGAs is much harder, when compared to an ASIC or a custom IC implementation. There are two reasons for this. The first pertains to the fixed size look-up tables. This leads to under utilization of the device. The second reason is that the pre-fabricated routing resources run out fast with higher device utilization.

Acknowledgments

Thanks be to Holy God, who is a constant strengthener in all the moments of my life. I thank my parents and husband for their dedicative support towards my studies. Thanks to Dr.P.Suyambu, Chairman, PSN Group of Institutions, for His encouragement and motivation for paper publications. Thanks to Dr.C.Gopi, Principal, PSNCET, for His wonderful guidance in publishing our paper. Thanks to all those who have helped me throughout this project .

References

[1] Refael c. Gonzalez and Richard E. Woods “Digital Image Processing” Delhi, India:Pearson Education, 2003

[2]Ayan sengupta, “Compressing still and moving images with wavelets” , Multimedia Systems,Vol-2, No-3, 994

[3]Robbins,“Advantages of FPGAs”, Renee Control Engineering [Control Eng.]. Vol. 57, no. 2, pp. 60-62. Feb 2010.

[4]A.Grzeszezak, M. K. Mandal, S. Panchanathan and T. Yeap, “VLSI Implementation of discrete wavelet transform” IEEE transactions on VLSI systems, vol 4, No 4,pp 421-433, Dec 1996

[5] SIAM J. Math. Anal, “The lifting scheme: A construction of second generation wavelets,” vol. 29, no. 2, pp. 511–546, 1997.

A.Alice Blessie has received her Bachelor of Engineering in Electronics and Communication Engineering from Anna University, Chennai in 2007 and now doing her master of engineering under the branch of Applied Electronics in Anna University, Tirunelveli. She is a student of PSN college of Engineering and Technology. She has participated in many National conferences and seminars. Her research interests include Digital Image processing, Neural networks.

J.Nalini has received her M.Sc (Electronics) from Bharathidasan University in the year 2005 and she has completed M.E (Communication systems) in Vinayaka Mission University in 2008.She is an Assistant Professor in the Department of Electronics And Communication Systems, PSN College of Engineering and Technology. Her research interests include Digital Image Processing and Wide Area Networks.

S.C.Ramesh is an associate professor of Department of Aeronautical Engineering. He has been served on programming committees and organizing committees of various international conferences and symposia. He is a member of IEEE.