International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 30 No. 3 May 2017, pp. 436-441

http://www.ijisr.issr-journals.org/

VLSI Implementation of Compression Engine using DWT/IDWT for JPEG 2000 in VHDL

***P.S. Neethu*[1] *and B. Gowri Shankari*[2]**

[1]Assistant Professor, Electronics and Communication engineering, New Prince Shri Bhavani College of Engineering and Technology, Chennai – 600072, Tamil Nadu, India

[2]Assistant Professor, Electrical and Electronics engineering, New Prince Shri Bhavani College of Engineering and Technology, Chennai – 600072, Tamil Nadu, India

ABSTRACT: 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. In order to reduce complexities of the design, linear algebra view of DWT and IDWT has been used in this paper. This design can be used for image compression in a robotic system.

KEYWORDS: discrete wavelet transforms (DWT); image compression; thresholding; VLSI design; JPEG 2000.

1 INTRODUCTION

Microchips are complex, tiny modules that provide logic circuitry or store computer memory. A chip is manufactured from a wafer of silicon (or, in some special cases, a sapphire), which is first cut to size and then etched with circuits and electronic devices. A chip is also sometimes called an IC or integrated circuit. VLSI (Very Large Scale Integration) is the level of microchip miniaturization and refers to microchips containing hundreds of thousands of transistors. Many special-purpose chips, known as application-specific integrated circuits, are being made today for automobiles, home appliances, telephones, and other devices.

Digital design was a manual process of designing and capturing circuits using schematic entry tools in the earlier days. With the advent of VLSI technology designers could design single chips using more number of transistors. Because of the complexity of these circuits, it was not possible to verify these circuits on a breadboard. Computer aided techniques became critical for verification and design of VLSI digital circuits. Programs to do automatic placement and routing of circuit layouts also become popular. In the digital design field, designers felt the need for a standard language to describe digital circuits.

Thus Hardware Description Languages came into existence. These are software-programming languages used to model the intended operation of a piece of hardware. Though HDLs were very popular for logic verification, designers had to manually translate the HDL based design into a schematic circuit with interconnections between gates. The advent of logic synthesis pushed the HDLs into the forefront of digital design. Designers could describe complex circuits at an abstract level in terms of functionality and dataflow by designing those circuits in HDLs. Logic synthesis tools would implement the circuit in terms of gates and gate interconnections. A common design is to design each IC chip, using an HDL, and then verify system functionality via simulation. A product is any electronic equipment containing Application-Specific Integrated Circuits (ASICs) or Field-Programmable Gate-Arrays (FPGA).

2 DWT ALGORITHM

2.1 THE JPEG 2000 COMPRESSION ENGINE

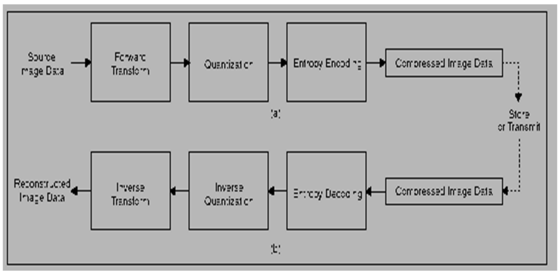

Figure: 1 The JPEG 2000 Compression Engine

At the encoder, the discrete transform is first applied on the source image data. The transform coefficients are then quantized and entropy coded before forming the output code stream (bit stream). The decoder is the reverse of the encoder. The code stream is first entropy decoded, dequantized, and inverse discrete transformed, thus resulting in the reconstructed image data. Although this general block diagram looks like the one for the conventional JPEG, there are radical differences in all of the processes of each block of the diagram. A quick overview of the whole system is as follows:

- The source image is decomposed into components.
- The image components are (optionally) decomposed into rectangular tiles. The tile-component is the basic unit of the original or reconstructed image.
- A wavelet transform is applied on each tile. The tile is decomposed into different resolution levels.
- The decomposition levels are made up of sub bands of coefficients that describe the frequency characteristics of local areas of the tile components, rather than across the entire image component.
- The sub bands of coefficients are quantized and collected into rectangular arrays of “code blocks.”
- The bit planes of the coefficients in a code block (the bits of equal significance across the coefficients in a code block) are entropy coded.
- The encoding can be done in such a way that certain regions of interest can be coded at a higher quality than the background.
- Markers are added to the bit stream to allow for error resilience.
- The code stream has a main header at the beginning that describes the original image and the various decomposition and coding styles that are used to locate, extract, decode and reconstruct the image with the desired resolution, fidelity, region of interest or other characteristics.

We have decomposed the whole compression engine into three parts: the pre-processing, the core processing, and the bit-stream formation part, although there exist high inter-relation between them. In the pre-processing part the image tiling, the dc-level shifting and the component transformations are included. The core processing part consists of the discrete transform, the quantization and the entropy coding processes. Finally, the concepts of the precincts, code blocks, layers, and packets are included in the bit-stream formation part.

2.1.1 IMAGETILING

The term “tiling” refers to the partition of the original (source) image into rectangular non-overlapping blocks (tiles), which are compressed independently, as though they were entirely distinct images. All operations, including component mixing, wavelet transform, quantization and entropy coding are performed independently on the image tiles (Fig. 2). The tile component is the basic unit of the original or reconstructed image. Tiling reduces memory requirements, and since they are also reconstructed independently, they can be used for decoding specific parts of the image instead of the whole image. All tiles have exactly the same dimensions, except maybe those at the boundary of the image. Arbitrary tile sizes are allowed, up to and including the entire image (i.e., the whole image is regarded as one tile). Components with different sub sampling factors are tiled with respect to a high-resolution grid, which ensures spa-tial consistency on the resulting tile components. In other words, larger tiles perform visually better than smaller tiles. Image degradation is more severe in the case of low bit rate than the case of high bit rate. It is seen, for example, that at 0.125 b/p there is a quality difference of more than 4.5 dB between no-tiling and tiling at 64 ×64, while at 0.5 b/p this difference is reduced to approximately 1.5 dB

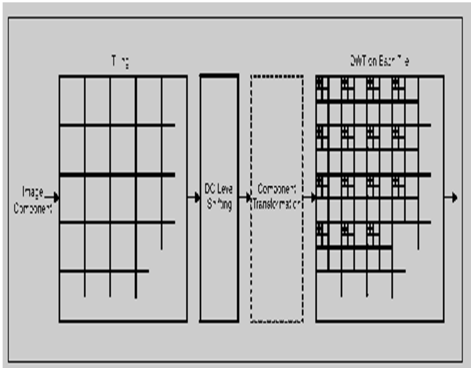

Figure: 2 Image Tiling

2.1.2 DC LEVEL SHIFTING

Prior to computation of the forward discrete wavelet transform (DWT) on each image tile, all samples of the image tile component are dc level shifted by subtracting the same quantity 2 P-1 , where P is the component's precision. DC level shifting is performed on samples of components that are unsigned only. Level shifting does not affect variances. It actually converts an unsigned representation to a two's complement representation, or vice versa.

2.1.3 COMPONENT TRANSFORMATIONS

JPEG 2000 supports multiple component images. Different components need not have the same bit depths nor need to all be signed or unsigned]. For reversible (i.e., lossless) systems, the only requirement is that the bit depth of each output image component must be identical to the bit depth of the corresponding input image component. Component transformations improve compression and allow for visually relevant quantization.

The standard supports two different component transformations, one irreversible component transformation (ICT) that can be used for lossy coding and one reversible component transformation (RCT) that may be used for lossless or lossy coding, and all this in addition to encoding without colour transformation. The block diagram of the JPEG 2000 multicomponent encoder is depicted in Fig. 3. (Without restricting the generality, only three components are shown in the figure. These components could correspond to the RGB of a colour image.

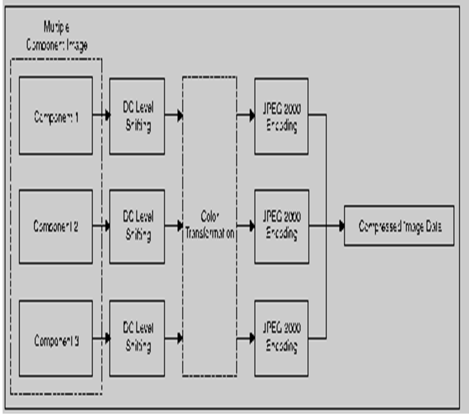

Figure: 3 JPEG 2000 Multicomponent Encoder Image Tiling

Since the RCT may be used for lossless or lossy coding, it may only be used with the 5/3 reversible wavelet transform. The RCT is a decorrelating transformation, which is applied to the three first components of an image. Three goals are achieved by this transformation, namely, colour decorrelation for efficient compression, reasonable colour space with respect to the human visual system for quantization, and ability of having lossless compression, i.e., exact reconstruction with finite integer precision.

2.1.4 CORE PROCESSING

Wavelet transform is used for the analysis of the tile components into different decomposition levels. These decomposition levels contain a number of subbands, which consist of coefficients that describe the horizontal and vertical spatial frequency characteristics of the original tile component. In Part I of the JPEG 2000 standard only power of 2 decompositions are allowed in the form of dyadic decomposition as shown in Fig. 6 for the image "Lena". To perform the forward DWT the standard uses a one-dimensional (1-D) subband decomposition of a 1-D set of samples into low-pass and high-pass samples. Low-pass samples represent a down-sampled, low-resolution version of the original set. High-pass samples represent a down-sampled residual version of the original set, needed for the perfect reconstruction of the original set from the low-pass set. The DWT can be irreversible or reversible. The default irreversible transform is implemented by means of the Daubechies 9-tap/7-tap filter [4]. The analysis and the corresponding synthesis filter coefficients in Table 3. The default reversible transformation is implemented by means of the Le Gall 5-tap/3-tap filter. The standard can support two filtering modes: convolution based and lifting based.

Convolution-based filtering consists in performing a series of dot products between the two filter masks and the extended 1-D signal. Lifting-based filtering consists of a sequence of very simple filtering operations for which alternately odd sample values of the signal are updated with a weighted sum of even sample values, and even sample values are updated with a weighted sum of odd sample values. For the reversible (lossless) case the results are rounded to integer values.

$$y(2n+1) = x_{ext}(2n+1) - \left\lfloor \frac{x_{ext}(2n) + x_{ext}(2n+2)}{2} \right\rfloor$$

$$y(2n) = x_{ext}(2n) + \left\lfloor \frac{y(2n-1) + y(2n+1) + 2}{4} \right\rfloor$$

Where x ext is the extended input signal and y is the output signal. The 5/3 filter allows repetitive encoding and decoding of an image without any loss. Of course, this is true when the decompressed image values are not clipped when they fall outside the full dynamic range (i.e., 0-255 for an 8 b/p image).

3 BLOCK DIAGRAMS OF DWT\IDWT

3.1 BLOCK DIAGRAM OF DWT

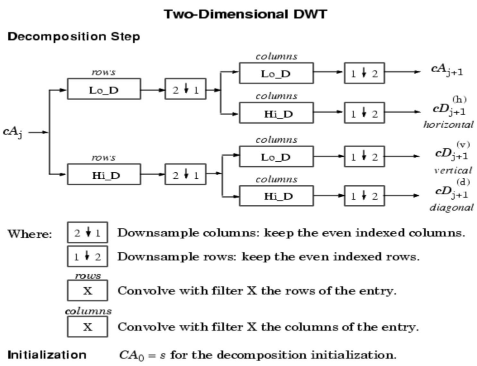

Figure: 4 Block Diagram of DWT

3.2 BLOCK DIAGRAM OF IDWT

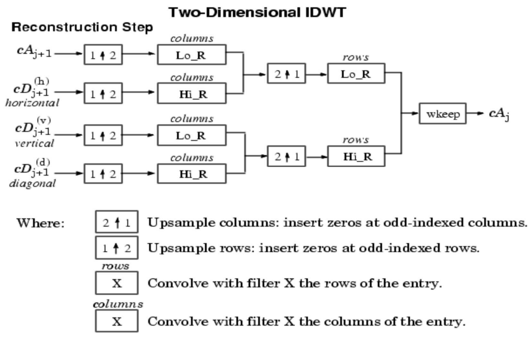

Figure:5 Block Diagram of IDWT

4 IMPLEMENTATION OF DISCRETE WAVELET TRANSFORMS IN VHDL

Discrete wavelet transformation (DWT) 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 behaviour 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.

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 theory is based on the fact that some signals, such as audio or video signals often carry redundant information. For instance, in a picture the neighbouring pixels often differ very slightly. The idea is to find a mathematical relation that connects neighbouring data samples (pixels) and reduces their number. The inverse process is needed to reconstruct the original. The low pass component can be subjected to another transformation of the same kind, decimating the original signal even more. This decorelation process can be continued until we are certain that neighbouring samples differ significantly enough. This is multilevel decomposition and it holds the key to time-frequency mapping of the spectral behavior of the signal. Also, this allows even better signal compression. Standard JPEG2000 for picture compression is based on this process.

The VHDL code here implements DWT using Le Gall 5/3 filter bank. The filtering process is called "lifted", this is more efficient than conventional approach using convolution. Also, integer arithmetic is used, and hence precision with more than 8 bits is not required. Additionally, the coefficients of Le Gall filter bank filters in "lifted" filtering are multiples of 2, so division and multiplication are replaced by shifting.

The system is divided into two parts, each containing a top level entity: DWT2D and IDWT2D. DWT2D is used for direct transformation and IDWT2D for inverse transformation. The entities require external memory source, were original data and coefficients are stored. Entities DWT and IDWT perform one-dimensional DWT and IDWT of the signal, stored in external memory. These two are based on 1D_SD and 1D_SR filtering process from the JPEG2000 standard.

The top level entities require parameters of transformation. Picture width and height should be specified along with the alignment of the rows in memory. The parameters are written using control signals. The process begins when number of levels of transformation is specified. Signal READY indicates that entity is busy (when low) or the transformation has finished and another can begin (when high). Top level entities configure DWT and IDWT in similar way.

There are two test bench configurations. Test DWT2D and testIDWT2D. Each uses input file to initialize memory. Configuration of DWT2D or IDWT2D instances is performed, supplying size of the picture and number of levels of decomposition. The result of the operation is written to a text file by dumping memory. Data Converter application is used to transform picture from known picture formats (bmp, jpg, gif...) into textual files used as input for test bench configurations. Pixels are level shifted prior to conversion.

5 SIMULATION RESULTS

ORIGINAL IMAGE

RECONSTRUCTED

2-D COMPRESSED

6 CONCLUSION

A model scheme for lossless image compression using DWT/IDWT for JPEG 2000 standard was successfully implemented using VHDL and the VLSI design was developed. The compression engine is capable of image decoding applications, both with integer and floating-point kernels. The customizable design allows setting the basic features of the decoder, such as maximum image size, maximum kernel length and computational precision. The synthesized decoder may be programmed to process images with different sizes, coded on a different numbers of layers and using different kernels, while always guaranteeing the correct mirroring operations at layers' borders.

By means of an on-chip cache and of a specifically optimized scheduling of operations, the decoder requires a minimum number of accesses to external memory, making it suitable for low-power embedded applications.

REFERENCES

[1] Multimedia communications: Applications, Protocols and standards- Fred Halsall

[2] Discrete time speech signal processing: principles and practice- Thomas.F.Quatier

[3] Principles of communication system second edition- Herbert Taube, Donald.L.Schilling

[4] Digital image processing- Gonzalez and woods

[5] Wavelet tutorials- Robipolkar,University of California

[6] Ten Lectures on wavelets- Ingrid Daubechies

[7] http://homepages.cae.wisc.edu/~ece533/images/,

[8] C.Nagarajan and M.Madheswaran – 'Analysis and Implementation of LLC-T Series Parallel Resonant Converter with Fuzzy controller'- International Journal of Engineering Science and Technology (IJEST), Applied Power Electronics and Intelligent Motion Control. Vol.2 (10), pp 35-43, December 2010

[9] C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[10] C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.

[11] C. Chakrabarti, M. Vishwanath and R. Owens, "Architectures for wavelet transforms," VLSI Signal Processing VI, IEEE special publications

[12] M. Vishwanath, "The recursive pyramid algorithm for the discrete wavelet transform," IEEE Transactions on Signal Processing, vol. 42, March 1994