VLSI DESIGN APPROACH FOR IMAGE COMPRESSION USING WAVELET

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ABSTRACT

This paper studies the implementation of VLSI Architecture of image compression system using wavelet. Discrete wavelet transform is the most widely used image compression technique and it is the most efficient algorithm used in JPEG image compression. An architecture that performs both forward and inverse lifting-based discrete wavelet transform is proposed. Conventional method requires more memory, area and power, lifting scheme is used as an enhanced method. Architecture of the DWT which is a powerful image compression algorithm is implemented using lifting based approach. This architecture results in reduced memory referencing, low power requirement, low latency and high throughput. The Inverse Discrete Wavelet Transform (IDWT) is also obtained in a similar way to get back the image matrix. The design can be used for both lossy and lossless compression. To reduce the complexities of the design, linear algebra view of DWT and IDWT has been used[1]. The advantages of the proposed architecture are the hardware optimization, fast computing time, regular data flow and reduce complexity. Because of the regular structure, the proposed architecture can be easily be scaled with the filter length and 2D DWT level. VLSI architecture for the 2-D DWT is implemented using FPGA in VHDL. With the growing popularity of the applications that use large amounts of image and video coding is an active and dynamic field. Image and Video Compression for Multimedia Engineering gives a basis for research and development.

Keywords:- Discrete Wavelet Transform(DWT), Inverse Discrete Wavelet Transform(IDWT), Field programmable Gate Array(FPGA), Very Large Scale Integration(VLSI)

1. INTRODUCTION

With the rapid development of VLSI design technologies, many processors based on text data and image data signal processing have been developed in the industry. The two-dimensional discrete wavelet transform (2D DWT) plays a major role in image or video compression standard, such as JPEG 2000. The Wavelet Transform(WT) provides an alternative approach to signal Processing, especially suited for the analysis of spatial and spectral locality. Discrete wavelet transform is an efficient tool for multi-resolution sub-band decomposition of signals. DWT is one of the fastest computation of wavelet transform. It is easy to implement and reduce the computational time and resources required. 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 cut off frequencies at different scales. The scaling factor and frequency parameter can be varied according to the application. Discrete Wavelet Transform (DWT) is a very useful tool in time-frequency analysis because of its excellent localization both in time and frequency. It has been very successful in research areas such as image compression. Data compression is the technique to reduce the redundancies in data representation in order to decrease data storage requirements and ultimately communication cost. 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. The data compression algorithms can be broadly classified in two categories – lossless and lossy. Usually lossless data compression techniques are applied on text data or scientific data. The discrete wavelet transform (DWT) is being increasingly used for image coding. It is due to the fact that DWT supports superior features like progressive image transmission by quality or by resolution. Recently, lifting scheme widely used for DWT leads a speed-up and a fewer computation compared to the classical convolution-based method. Daubechies and Sweldens first derive the lifting-based discrete wavelet transform to reduce complex operations. At present, many VLSI architectures for the 2-D DWT have been proposed to meet the requirements of real-time processing. The implementation of DWT in practical system has some issues. First the complexity of wavelet transform is several times higher than that of DCT. Second, DWT needs extra memory for storing the intermediate computational results. Moreover, for real time image compression, DWT has to process massive amounts of data at high speeds. The use of software implementation of DWT image compression provides flexibility for manipulation but it may not meet some timing constraints in certain applications. Hardware implementation of DWT, however, also has problems. The first difficulty is that the high cost of hardware implementation of multipliers. It is required approximately 256 transistors to build a delay element, 415 transistors for an adder and 6800 transistors for...
multiplier.[4] Several VLSI architectures have been proposed for DWT. The 2-D DWT is currently used in many image processing applications such as image and video compression, fractal analysis, and texture discrimination etc. Since, the 2-D DWT requires a large volume of computation; several architecture solutions are suggested in past for its efficient implementation. Advanced technologies have increased demands for visual information and higher quality video frames, as 3D movies, games and HDTV. This charges the available technologies and creates a gap between the huge amount of visual data required for multimedia application and the still-limited hardware capabilities. Images and Video compression for multimedia engineering bridges the gap with concise, up to date video and image coding information, with the growing popularity of the application that uses large amounts of visual data, image and video coding is an active and dynamic field. Image and Video compression for multimedia engineering builds a basis for future study, research and development. This paper proposes high performance architecture for image compression which is based on the frequency domain representation. The proposed architecture is developed using verilog Hardware Descriptive Language and has been tested for still images.

2. DESIGN METHODOLOGY

2.1 DWT implementation

Filters are 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 algorithm consists of Forward DWT (FDWT) and Inverse DWT (IDWT). The FDWT is computed by successive low pass and high pass filtering of the discrete time-domain signal as shown in fig.1.

![Figure 1: Block diagram of Conventional FDWT](image)

The preliminary work in convolution DWT is to build 1D-DWT modules which are composed of high pass filter (HPF) and low pass filter (LPF) that performs convolution of filter co-efficient and input pixels.[1] Most natural images have smooth colour variations, with the fine details being represented as sharp edges in between the smooth variations. Technically, the smooth variations in colour can be termed as low frequency components and the sharp variations as high frequency components.

In wavelet analysis, A signal can be separated into approximations (Approx) or averages and detail coefficients. Averages are the high-scale, low frequency components of the signal. The details are the low scale, high frequency components. If we perform forward transform on a real digital signal, we wind up with twice as much data as we started with. That’s why after filtering down sampling has to be done. Similarly we can perform Inverse DWT to get the reconstructed image by matrix multiply method. Figure for IDWT is shown fig.2.

![Figure 2: Block Diagram of Inverse DWT (IDWT)](image)

Since conventional method requires more computations, area and power, an enhanced method which is known as lifting scheme is implemented and it is used as Low Power Technique.

2.2 LIFTING SCHEME DWT

The lifting scheme is a well known method for constructing bi-orthogonal wavelets. The main difference with the classical construction is that it does not rely on the Fourier transform. The lifting scheme is a technique for both, designing wavelets and performing the discrete wavelet transform. The lifting scheme is an efficient implementation of a wavelet transform algorithm. It was primarily developed as a method to improve wavelet transform, and then it was extended to a generic method to create so-called second-generation wavelets i.e. wavelets which do not necessarily use...
the same function prototype at different levels. Second-generation wavelets are much more flexible and powerful than the first generation wavelets. The lifting scheme is an implementation of the filtering operations at each level. Lifting scheme consists of three steps: First step is called Split In this step, the data is divided into ODD and EVEN elements. Second step is called Predict In the PREDICT step uses a function that approximates the data set. The differences between the approximation and the actual data replace the odd elements of the data set. The even elements are left unchanged and become the input for the next step in the transform. The PREDICT step, where the odd value is "predicted" from the even value is described by the equation:

\[ \text{Oddy+1}, x = \text{Oddy}, x - P(\text{Eveny}, x) \]  

(I)

The third step is termed as Update. In the UPDATE step replaces the even elements with an average. These gives a smoother input for the next step of the wavelet transform. The odd elements also represent an approximation of the original data set, which allows filters to be constructed. The UPDATE phase follows the PREDICT phase. The original values of the odd elements have been overwritten by the difference between the odd element and its even "predictor". So in calculating an average the UPDATE phase must operate on the differences that are stored in the odd elements:

\[ \text{Eveny+1}, x = \text{Eveny}, x + U(\text{Oddy+1}, x) \]  

(II)

A simple lifting scheme forward transform is shown in the following figure.3

![Figure 3 Block diagram for Forward lifting scheme](image1)

One of the elegant features of the lifting scheme is that the Inverse transform is a mirror of the forward transform. Inverse Lifting Scheme block schematic is shown in the following figure.4

![Figure 4 Block diagram for Inverse lifting scheme](image2)

Here in inverse lifting scheme all the steps are similar to forward lifting scheme except split step is replaced by merge step.

### 2.3 IMPLEMENTATION OF DWT ALGORITHM

In this section first we will discuss how to implement FDWT and IDWT in MATLAB environment. In the FDWT part the input data will be transferred from time domain to scale domain and in the IDWT part the coefficients will be transferred back into time domain. While implementing the algorithm in MATLAB the matrix multiplication method has been used. After we have achieved satisfactory result in MATLAB we proceed to the next stage where we translate the code into VERILOG. The development of algorithm in VERILOG is different in some aspects. The main difference is unlike MATLAB, VERILOG does not support many built in functions such as convolution, max, mod and many more. So while implementing the algorithm in VERILOG, linear equations of FDWT and IDWT is used.

### 3 SIMULATION RESULT

![Figure 5 Original Input Rose Image](image3)
Figure 6  First level Approximation And Detail Coefficients

Figure 7  First Level Reconstructed Image

Figure 8  Second level Approximation And Detail Coefficients
Figure 9  second Level Reconstructed Image

Figure 10 Output Recovered Rose Image

Figure 11 MATLAB output window showing compression
4 CONCLUSION AND FUTURE SCOPE

Here the input image is read in MATLAB environment then its approximate and details coefficients are achieved by different decomposition levels. Compression ratio is also achieved which is shown in MATLAB editor window. 2D DWT is done, we can choose the decomposition level. Care should be taken that the recovered image should match the original input image. This code will work for both lossy and lossless images, so we can have the input image likes satellite image, medical image, biometrics images. For hardware realization of the compression we need to convert the it from MATLAB environment to VHDL environment. Which will give us the VLSI approach to design the compression of the image. For the same image in matrix form VHDL code is written to get the VLSI architecture of the compression technique. After generating the bit file which can also be implemented using FPGA devices. In future scope we can try the same for real time operations in multimedia applications. RTL view is also observed first before final design of the product. Xilinx system generator tool is also used for synthesizing the design. We can also use the Verilog HDL for hardware realization of the compression techniques. This will work for both lossless and lossy image compression techniques.

REFERENCES


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