

VHDL design of lossy DWT based image compression technique for video conferencing

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Abstract

In certain applications like Video Conferencing and Television, large amount of images are transmitted through internet. It necessitates an image compression technique to utilize the bandwidth. In this work a scheme of Compression technique is proposed based on the combination of 2-D DWT/Huffman Encoding. An aim of the work is to compress an image using Discrete Wavelet Transform and Huffman encoding, to implement DWT using VHDL, to implement Huffman encoding using VHDL and to measure the performance in terms of compression ratio for five different images. The first part of the work presents an implementation of Discrete wavelet Transform with Haar wavelet and second part of the work presents an implementation of Huffman encoding. The performance will be measured in terms of Compression ratio.

Keywords: Discrete Wavelet Transform, Image Compression, Huffman Encoding.

1. Introduction

Generally, the 2- D DWT is frequently applied in image and video processing. The discrete wavelet transform (DWT) has been widely used in audio and image processing, digital communications and other application fields. This computation transform has been widely implemented in very-large-scale integration (VLSI) because of the real-time requirement. Wavelets are functions defined over a finite interval. The basic idea of the wavelet transform is to represent an arbitrary function as a linear combination of a set of such wavelets or basis functions. These basis functions are obtained from a single prototype wavelet called the mother wavelet by dilations (scaling) and

Translations (shifts). The purpose of wavelet transform is to change the data from time-space domain to time-frequency domain which makes better compression results. The fundamental idea behind wavelets is to analyze the signal at different scales or resolutions, which is called multiresolution.

2. DWT based Image compression technique video conferencing

A scheme of Compression technique is proposed based on the combination of 2-D DWT and Huffman Encoding to Compress an input image by reducing the coding redundancy. Here, the Discrete wavelet transform and Huffman coding are implemented using VHDL. Input image size of 256x256 is read using MATLAB R2012 and Image Pixels are stored in Memory block module to perform Discrete Wavelet Transform. Here, the image compression technique is based on Discrete wavelet transform and Huffman Coding. Approximation coefficients are obtained from DWT using VHDL source code. Huffman coding of approximation coefficients are obtained using VHDL and Compression ratio is measured. Simulation of DWT and Huffman Coding using Modelsim is performed. The block diagram of proposed work is shown in Fig 1.

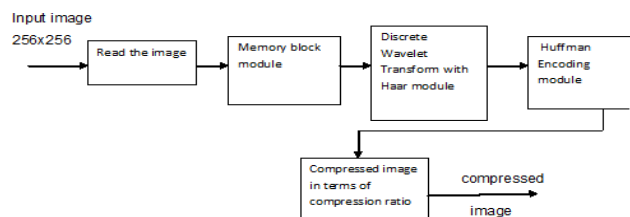


Fig. 1 Block Diagram

2.1 Algorithm for 2-D DWT

Discrete wavelet transform algorithm is also known as Subband coding. Assume the highest frequency component that exists in a signal will be π radians. To provide sufficient information about the signal without its loss due to sampling, the signal is sampled at Nyquist's rate (which is twice the maximum frequency that exists in the signal). Next, the signal is passed through two filters – one half band low pass and one half band high band filter. The output of the high pass filter is preserved. After passing the signal through a half band low pass filter, half of the samples can be eliminated according to the Nyquist's rule, since the signal now has a highest frequency of $\pi/2$ radians instead of π radians. Simply discarding every other sample will subsample the signal by two, and the signal will then have half the number of points. The scale of the signal is now doubled. Note that the low pass filtering removes the high frequency information, but leaves the scale unchanged. Only the sub sampling process changes the scale. Resolution, on the other hand, is related to the amount of information in the signal, and therefore, it is affected by the filtering operations. Half band low pass filtering removes half of the frequencies, which can be interpreted as losing half of the information. Therefore, the resolution is halved after the filtering operation.

Note, however, the sub sampling operation after filtering does not affect the resolution, since removing half of the spectral components from the signal makes half the number of samples redundant anyway. Half the samples can be discarded without any loss of information. In summary, the low pass filtering halves the resolution, but leaves the scale unchanged. The signal is then sub sampled by 2 since half of the number of samples is redundant. This doubles the scale.

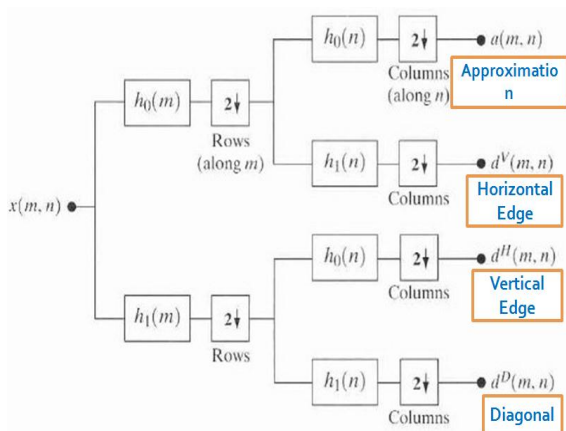


Fig. 2 Decomposition of an image

The Haar wavelet is the simplest wavelet.

$$wH(x) = \begin{cases} 1 & 0 < x < 1/2 \\ -1 & 1/2 < x < 1 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

The mother wavelet obviously satisfies the two wavelet requirements, as it is both local and oscillatory.

The picture below shows the shapes of Haar wavelets for various scales and translations.

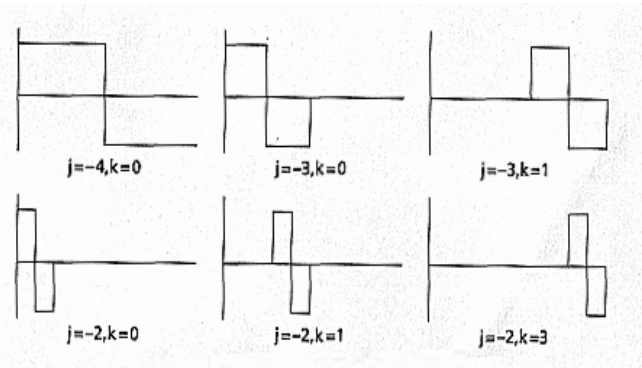


Fig.3 Shape of the Haar Wavelets

Wavelet Transform is a type of signal representation that can give the frequency content of the signal at a particular instant of time or spatial location. The Haar wavelet transform decomposes the image into different sub-band images. It splits component into numerous frequency bands called sub-bands. They are LL, LH, HL, and HH sub-bands. A high-frequency sub-band contains the edge information of input image and LL sub-band contains the clear information about the image. Discrete wavelet transform (DWT), which transforms a discrete time signal to a discrete wavelet representation. It converts an input series x_0, x_1, \dots, x_m , into one high-pass wavelet coefficient series and one low-pass wavelet coefficient series (of length $n/2$ each). In this work, image size of 256×256 is used. A 256×256 pixel gray scale image is stored as a 256×256 matrix, with each element of the matrix being a number ranging from zero (for black) to some positive whole number (for white). A 256×256 color image is stored as three 256×256 matrices (One each for the colors red, green, and blue). We can use this matrix, and some linear algebra to maximize compression while maintaining a suitable level of detail.

2.2 Huffman Encoding

Huffman code is a Optimum prefix code developed by D. Huffman in a class assignment.

Construction of Huffman codes is based on two ideas:

1. In an optimum code, symbols with higher probability should have shorter code words

2. In an optimum prefix code, the two symbols that occur least frequently will have the same length (otherwise, the truncation of the longer codeword to the same length still produce a decodable code).

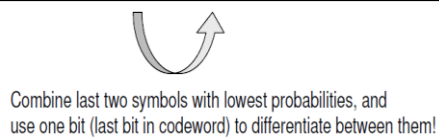
Huffman coding is a popular method for compressing data with variable-length codes. Given a set of data symbols (an alphabet) and their frequencies of occurrence (or, equivalently, their probabilities), the method constructs a set of variable-length codewords with the shortest average length and assigns them to the symbols. Huffman coding serves as the basis for several applications implemented on popular platforms. Some programs use just the Huffman method, while others use it as one step in a multistep compression process.

A. Principle of Huffman coding

Starting with two least probable symbols, g and d, of an alphabet A, if the codeword for g is [m]0, the codeword for d would be [m]1, where [m] is a string of 1s and 0s. Now, the two symbols can be combined into a group, which represents a new symbol y in the alphabet set. The symbol y has the probability P(g) + P(d). Recursively determine the bit pattern [m] using the new alphabet set. Let $A = \{a_1, \dots, a_5\}$, $P(a_i) = \{0.2, 0.4, 0.2, 0.1, 0.1\}$.

Table 1: Principle of Huffman coding

Symbol	Step 1	Step 2	Step 3	Step 4	Codeword
a_2	0.4	0.4	0.4	0.6	1
a_1	0.2	0.2	0.4	0.4	01
a_3	0.2	0.2	0.2	0.2	000
a_4	0.1	0.2			0010
a_5	0.1				0011



B. Huffman Code

The Huffman code for the approximation coefficients are shown in the Table 2.

Table 2: Huffman code

Codeword length	First_codeword	Num_codewords_I[]	Codeword_offset
4	15(1111)	1	0
5	22(10110)	8	1
6	35(100011)	9	9
7	57(0111001)	13	18
8	44(00101100)	70	31
9	35(000100011)	53	101
10	53(0000110101)	17	154
11	91(00001011011)	15	171
12	00(00000000000)	182	186

3. Results and Discussion

The Different colour images are given as an input for the DWT based imaged compression. The input images are shown in Fig 4.

3.1 Input images



Fig. 4 Input images

3.2 Implementation of Discrete Wavelet Transform

Discrete Wavelet Transform with Haar wavelet is simulated using VHDL. Memory block module is used to store the image pixel values, then the pixels are read from memory through the data lines and Wavelet Coefficients are obtained. The LL, LH,HL,HH Coefficients are calculated using wavelet decomposition. The simulation output of DWT for an image is shown in Fig

3.3 Implementation of Huffman coding

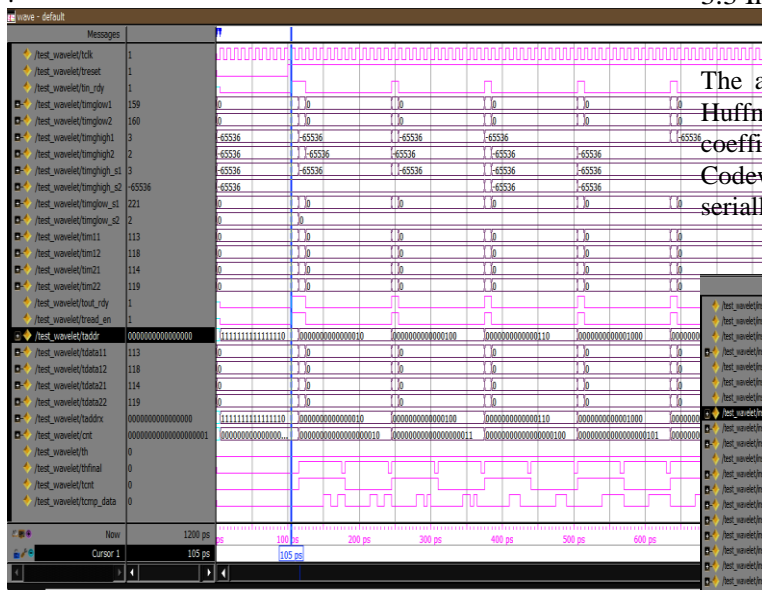


Fig. 5 Simulation output for DWT

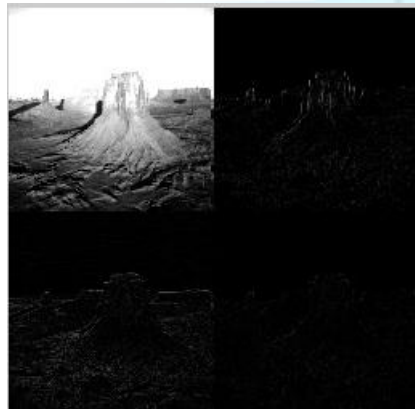


Fig. 6 DWT Coefficients

The approximation coefficients are given as an input to Huffman data Table to obtain the Huffman index for each coefficient. Huffman code variable has an input of Codeword length and the compressed data is viewed as serially. This is shown in Fig 7.



Fig. 7 Simulation output for Huffman coding

4. Conclusion

In this work, an efficient compression technique that uses Huffman encoding for the approximation coefficients of the given images has been successfully developed. The performance of the proposed technique is evaluated in terms of compression ratio for five different images. It is found that the compression ratio has decreased significantly as only approximation coefficients are considered as the same time the quality of image has been compromised as detailed coefficients are left out. The proposed lossy compression technique is highly suitable for applications like video conferencing but not that suitable for medical image transmission also the compression ratio can be further reduced by incorporating quantization of the approximation coefficients.

Table 3: Comparison of Compression ratio for five different images

Images	Compression ratio
Desert	0.9478
Hydrangeas	0.9389
Lighthouse	0.9532
Penguins	0.9524
Tulips	0.9536

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