Discrete Wavelet Transform Based Image Compression using Frequency Band Suppression and Throughput Enhancement

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Abstract

Discrete Wavelet Transform is an effective and important process in digital image processing. The Discrete Wavelet Transform is used for significant compression, segmentation, classification, image enhancement and image fusion of web images that are to be viewed in short page loading time with bandwidth as major constraint. The DWT provides spatial frequency information and the spatial location. The main advantage of this nature is that concurrent information helps us to reduce redundancy and increases the bandwidth more efficiently. The spatial locations of the image may or may not contain variations and at certain times may be constants also. A signal which is constant does not carry significant information. If the coefficients of constant signal are encoded along with other spatial location coefficients it is memory wastage. Discrete Wavelet Transform if applied to the image as a whole results in better frequency resolution and good spatial resolution. But still this spatial resolution is not that good. This work aims in improving the spatial resolution further. The image is segmented in space into small sub-images and Discrete Wavelet Transform is applied recursively to each and every sub image. Since the target image is spatially small in resolution as well, the same operation can be achieved with smaller Discrete Wavelet Transform Unit. Since there are only few pixels at any given processing time is faster and the bandwidth, throughput is high. Because of large throughput the entire operation can be pipelined and done in a serial manner. The proposed work reduces the number of DWT unit required for the process.

Keywords: Image Processing, Discrete Wavelet Transform, Image Compression, Segmentation

1. Introduction

Wavelets are mathematical functions which decompose the input signal into a number of frequency components in different scale. Wavelet can be used for maximum compression of the image using less storage space retaining its quality. An image contains horizontal, vertical and diagonal details. The scale used characterizes diverse resolutions possible using wavelet transform. If the scale is large it provides good frequency resolution and poor time resolution. If the scale is small it provides good time resolution and poor frequency resolution. The scale can be compared to a variable representing frequency in wavelet transform. Wavelet analysis is a perfect tool to analyse data with sharp discontinuities which is common with image data type. The mother wavelet is used to derive other wavelets that are used for data analysis. 2D Discrete

Wavelet Transform Technique is widely used for audio and video compression. In many signal processing applications, the determination of time occurrence of a certain frequency component may sound interesting. In such cases it will be very useful to know the time interval of occurrence of these frequency components. Wavelet transform can provide time and frequency information simultaneously, providing time frequency representation of the signal.

2. Literature Survey

Sonja Grgic [1] has proposed a method for image compression using multiple wavelets. The type of the wavelet used for compression is chosen based on the application. The work describes the basis of wavelet based image compression. Colm Mulchay [2] has described image compression using Haar Wavelet. The wavelet coefficients are encoded according to the level of details. The information is also processed in parallel architecture. Kamrul Hasan [3] has stated that it becomes necessary to handle large amount of information in this digital age. Wavelets provide a method for encoding the digital data efficiently. A 2D image compression technique using wavelets as the basis functions is described and the method to measure the quality of the compressed image is proposed.

M.Mozammel Hoque [4] stated that digital data is vast as far as images are concerned. For effective transmission the data size should be reduced. Method for high compression of digital image with unnoticeable degradation is proposed. Y.Sukanya [5] proposed a method for image compression based on processing time, error comparison, mean square error, peak signal to noise ratio and compression ratio. V. Alarcon-Aquino [6] has discussed about lossy wavelet compression techniques and other techniques based on thresholding.

Akshay Kekre [7] has discussed about image compression using wavelet transform and differential pulse code modulation technique. In the first stage wavelet transform is applied to the image. In the second stage differential pulse code modulation is applied to the wavelet coefficients. Three types of discrete wavelet transform based on perfect translation invariance theorem was proposed by Hiroshi Toda [8]. Efficient VLSI architectures for constructing 1D and 2D Discrete Wavelet Transforms is proposed by Chao-Tsung Huang [9]. Discrete time transform based on discrete mother wavelet is proposed by Wei Zhao [10].

3. DISCRETE WAVELET TRANSFORM

Discrete wavelet transform is a method used to decompose any discrete time signal into wavelets. The Wavelet Transform method cannot be directly applied to a sampled signal. This is because the amplitude of the signal between two successive samples is undefined. To overcome this problem Discrete Wavelet Transform is introduced. If mathematical formula is used to compute wavelet coefficients the process is tedious. So filtering technique is used. Both high pass and low pass filters are applied consecutively and the image is down sampled at each stage. The high pass and low pass filters are related to each other as given by the following equation:

$$g[L-1-n] = (-1)^n h[n] \qquad (1)$$

Where g[n] is the impulse response of the high pass filter and h[n] is the impulse response of the low pass filter. After low pass filtering and high pass filtering the image can be down sampled. After filtering the frequency resolution of the image is doubled because the spectrum of the output of the filter contains only half of the frequencies in the input spectrum. The scale is divided by two on successive down sampling.

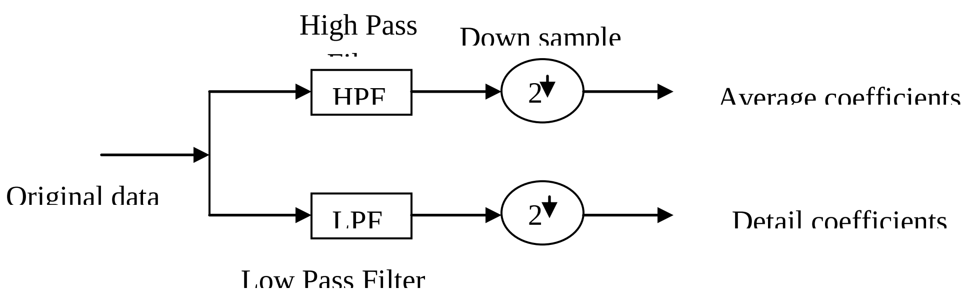

Figure 1 Discrete Wavelet Transform

The Discrete Wavelet transform is applied to the sampled signal by successive filtering and down sampling. The process is shown in Figure 1. Filtering reduces the resolution or information content in the signal by a factor of two. The frequency resolution of the signal is doubled by filtering. The time resolution of the signal is halved by a factor of two.

In 2D Discrete Wavelet Transform the filter is applied to the data row wise and column wise. The output of the filter is down sampled both row wise as well as column wise. If the input 2D data say an image consist of M rows and N columns then by applying the filter column wise and down sampling we get an image of resolution M/2 X N. Then the same filter is applied row wise and the output of the filter is down sampled. Now the image has a resolution M/2 X N/2. Now we have four sub band images which are termed as LL, LH, HL, HH. LL is the low frequency subband in the low frequency region. LH is the high frequency subband in the high frequency region. HL is the low frequency subband in the high frequency region. HH is the high frequency subband in the high frequency region. The 2D discrete wavelet transform is shown in Figure 2.

Table 1 Comparison of Filters Required Stage wise

Stage Number	Multiresolution Wavelet Analysis	Multiband Wavelet Analysis	Reduction in Number of Filters
1	2	D	2-D
2	4	D	6-D
3	8	D	14-D
4	16	D	30-D
5	32	D	62-D

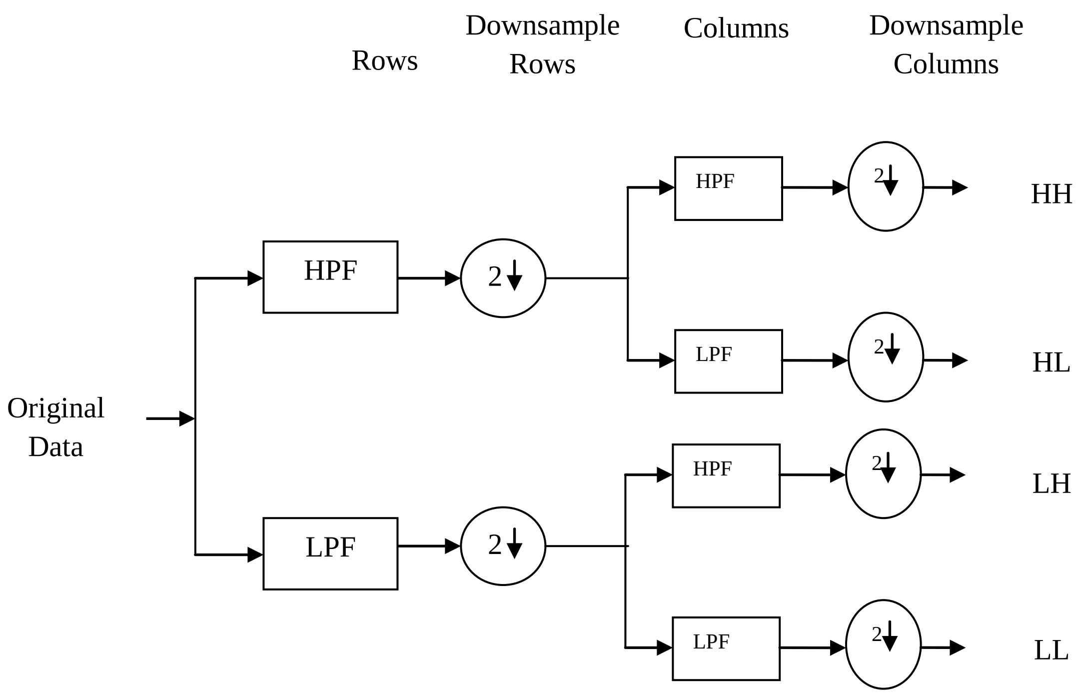

Figure 2 2D-Discrete Wavelet Transform

4. IMPLEMENTATION OF IMAGE COMPRESSION USING MULTI-BAND WAVELET TRANSFORM

In conventional wavelet transform the image is successively passed through specially designed high pass and low pass filters and then subsampled. In this method either of the frequency resolution is poor. If high frequency resolution is good the low frequency resolution is poor and vice versa. If both high pass and low pass filters are used it requires large number of filters. To overcome this problem wavelet transform based on multi band analysis and synthesis filter banks is proposed. The frequency resolution in this method is very good against all frequency bands. The down sampling rate is determined by the sampling theorem. If the total spectrum is divided into D bands using filters with appropriate cut off frequencies, then the output of each filter can be subsampled by a factor of D. The output of the filters gives the different wavelet coefficients. The coefficients from all filters which have least amplitude can be neglected for reconstruction. Since majority of the coefficients have least amplitude the image can be maximally compressed. 2D Wavelet Transform implemented using multiband filters is shown in Figure 3. As an example D=6 is chosen for reference. It is evident from Table 1 that the complexity of Multiband Wavelet Analysis does not grow with number of stages. The complexity is always O (D) which is the number of sub bands into which we decompose the input signal. Considering the first stage the reduction in the number of filters is -4 which means that there are four additional filters used than conventional wavelet transform.

5. Results and Discussion

The simulation is done with the help of Modelsim and MATLAB. The image file is read using MATLAB and stored as a matrix. The matrix contains the input data. A low pass filter with cut-off frequency π/2 rad/sec is used as analysis filter. For simplicity the image is divided into two sub bands. The sub band 1 consists of frequency in the range 0 to π/2 rad/sec and the sub band 2 consists of frequency in the range of π/2 to π. The matrix data is given as input to the filter column wise and the output from the filter is stored in a text file. The text file is read using MATLAB and the image is displayed. The input image is shown in Fig 3.

Figure 3 The Input to the Image Processing System

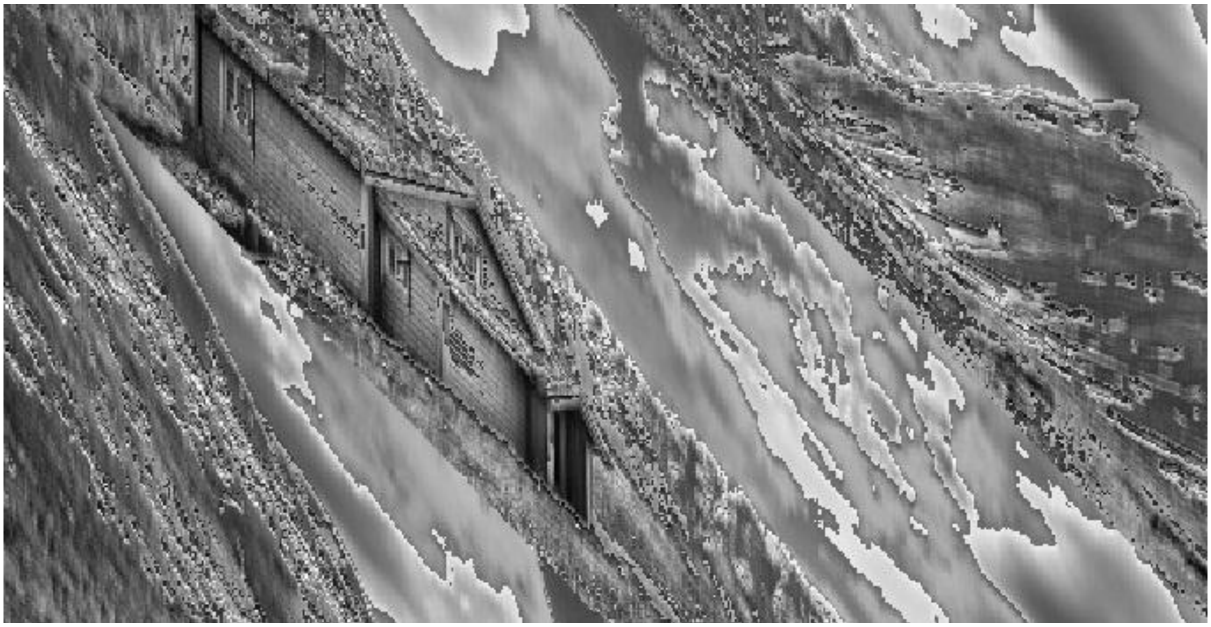

Figure 4 The Discrete Wavelet Transform Output

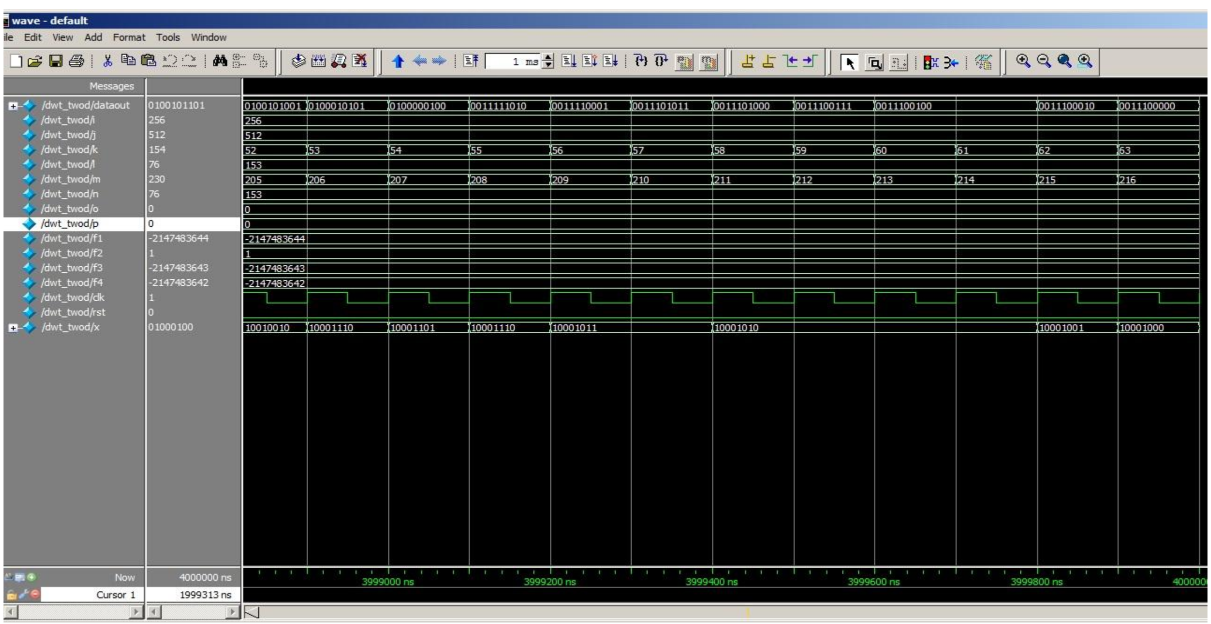

Figure 5 Simulation Output of Image Processing System

The simulation output using Modelsim tool is shown in Figure 5. The first signal in the image is the data out from the filter. The output from the filter displayed as image using MATLAB is shown in Figure 4.

6. Conclusion

In this work Multiband Wavelet Analysis is done. The Multiband Wavelet analysis significantly reduces the number of sub band filters required. The proposed method has good down sampling rate thereby reducing the resolution of the output image by a large factor. Hence the sub band image occupies less space.

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