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Implementation of Image Compression using Multi-Band Wavelet Transform

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ABSTRACT

In this paper image compression using multi band wavelet analysis is implemented. The wavelet transform is a very important technique for signal compression. The wavelet transform decomposes the input signal into a number of subband signals. Each subband has enhanced frequency resolution. In conventional discrete wavelet transform for a sample of 256 points there are 8 decomposition levels. Each decomposition level consists of several wavelet coefficients. Majority of coefficients do not carry sufficient information. Therefore decomposition of 8 levels involves processing of redundant samples. The main aim of this work is to avoid processing of redundant samples and unnecessary decomposition by filtering out and under sampling the input sequence. First level decomposition itself yields good data compression with fine picture quality.

Keywords: Discrete Wavelet Transform (DWT), Very Large Scale Integration (VLSI), Analysis Filter Bank.

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, the frequency resolution is good and time resolution is poor. 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. Wavelet Transform was developed as an alternative to Short Time Fourier Transform to overcome the shortcomings.

In this work the image is passed through a set of high pass and low pass filters. Each filter removes half of the bands in the original image. Followed by filtering the input image is down sampled by a factor of two. Since down sampling is followed by filtering the Nyquist sampling rate is still valid. The paper is divided into sections. Section II describes the necessary prerequisites for the work. The filters used to find wavelet co-efficient are described in section III. Section IV describes the proposed work.

2. LITERATURE SURVEY

[Grgiæ, et al, 1999] 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

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based image compression. [Colm, 1997] 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. [Talukder, et al, 2010] 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.

[Chowdhury, et al, 2012] 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. [Sukanya, et al 2013] proposed a method for image compression based on processing time, error comparison, mean square error, peak signal to noise ratio and compression ratio. [Alarcon-Aquino, et al, 2013] has discussed about lossy wavelet compression techniques and other techniques based on thresholding.

[Akshay Kekre, et al, 2013], et al, 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 [Toda, et al, 2011]. Efficient VLSI architectures for constructing 1D and 2D Discrete Wavelet Transforms is proposed by [Huang, et al, 2002]. Discrete time transform based on discrete mother wavelet is proposed by [Zhao, et al, 1999].

3. FOURIER TRANSFORM

The Fourier Transform is a mathematical operation used to represent any signal without discontinuities as sum of cosine and sine waves. A sine wave integrated with a sine wave of same frequency yields a finite value. When it is integrated with a sine wave of different frequency the result is zero. This property can be used to extract all sine frequency components in the input signal. The same is true with cosine wave also and hence the cosine frequency components can also be extracted in the same manner. Using this principle the Fourier Transform converts a time domain signal into a signal in frequency domain. The output of the Fourier Transform is the amplitude and phase of the sine and cosines as a function of the radian frequency.

a) *Short Time Fourier Transform*: The problem with Fourier Transform is that it has poor time resolution in the frequency domain. To overcome this problem the Short Time Fourier Transform is used. The Short Time Fourier Transform uses windows to select the input signal within a particular time interval. Fourier Transform is applied to each time interval of the input signal. In this manner the time of occurrence of a certain frequency component can be found out. As the window size decreases the time resolution increases and frequency resolution decreases. As the window size increases the time resolution decreases and frequency resolution increases. If the window size tends to infinity the Short Time Fourier Transform becomes equal to the Fourier Transform itself.

b) *Wavelet Transform*: To overcome the shortcomings of the Short Time Fourier Transform, Wavelet Transform is developed. Wavelet means an oscillation for a very short period of time. It is a small wave. All wavelets are derived from the basis function. Each wavelet provides different time resolution and different frequency resolution. To change the resolution the wavelet uses a parameter called as scale. When scale increases the time resolution increases and frequency resolution decreases. When scale decreases time resolution decreases and frequency resolution increases. Resolution here means the ability to find the exact value accurately. When scale increases the wavelet shrinks to short duration oscillations. Hence the time of occurrence of a frequency component can be found accurately and hence good time resolution. But all the frequency components present in the input signal cannot be determined. To find the frequency components we have to substitute a scale value and all the frequency values. If the frequency component does not show up minimum amplitude then the scale is changed and the entire procedure is repeated once again.

c) *Discrete Fourier Transform*: The amplitude and the frequency variables in Fourier Transform take continuous values. The input to the transform is a continuous time signal. The output is a spectrum continuous in frequency. The data processed by a computer is the sampled version of the original continuous time signal. The sampling is done at Nyquist rate. Hence there is a need to compute transforms for the sampled version of the signal and it is here Discrete Fourier Transform comes into place. The input to the Discrete Fourier Transform is the sampled version of the original signal. The output is a spectrum which is discrete. The spectrum may be assumed to be the sampled version of the actual spectrum.

4. 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. The process of using mathematical formula to compute wavelet coefficients 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:

$$g[L-1-n] = (-1)^n h[n] \tag{1}$$

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.

The Discrete Wavelet transform is applied to the sampled signal by successive filtering and down sampling. The process is shown in Fig.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

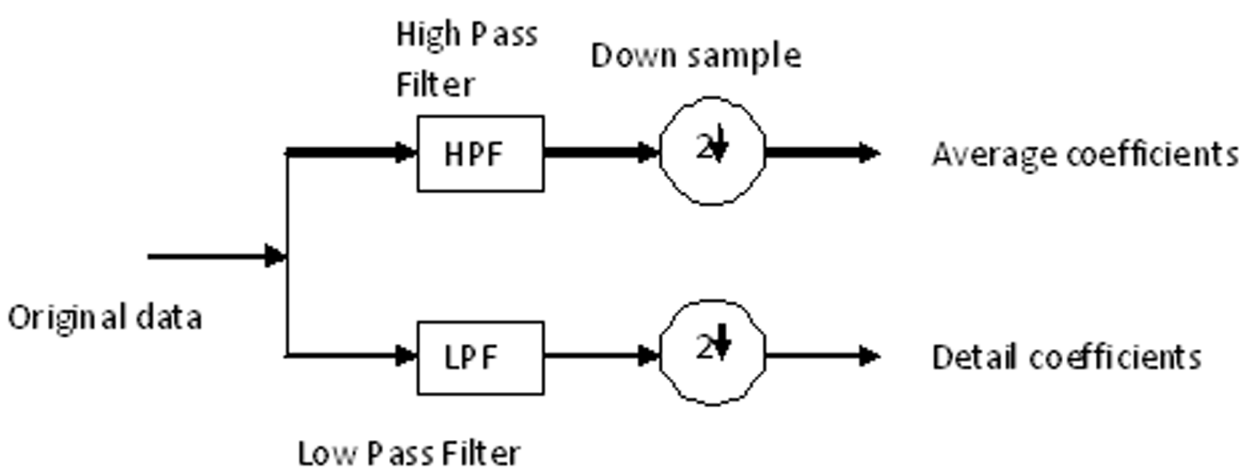

Figure 1: Discrete Wavelet Transform

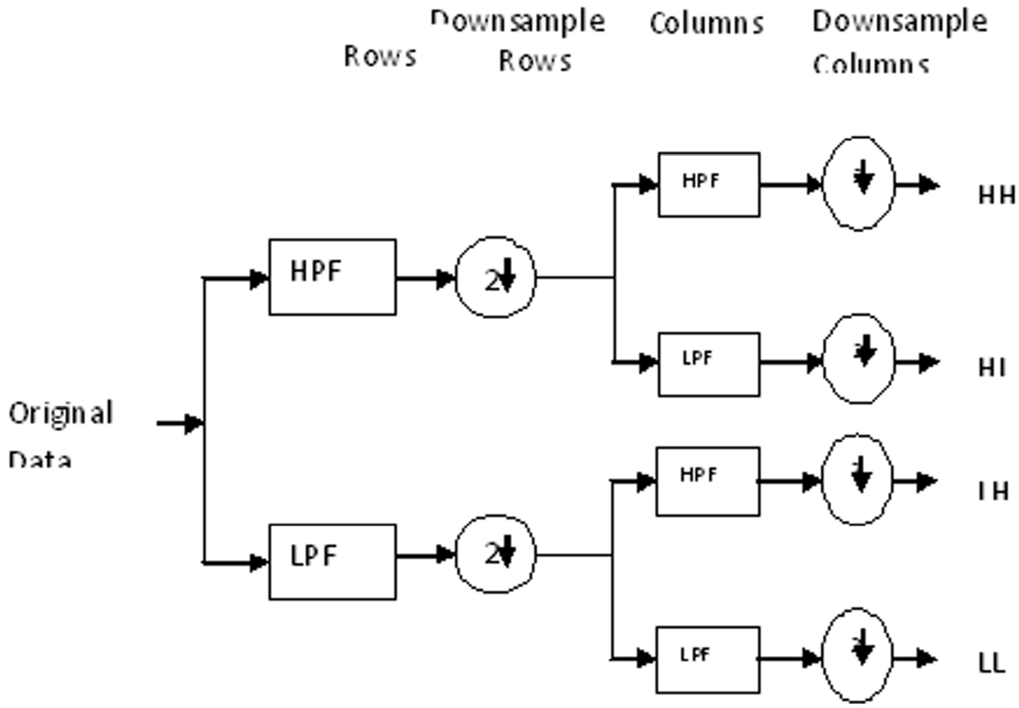

Figure 2: 2D-Discrete Wavelet Transform

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 Fig.2.

It is clear from the diagram that the First Level decomposition in conventional method requires two filters. The Second Level Decomposition requires four filters. The Third Level Decomposition requires eight filters. In general the n th level decomposition requires 2n filters. The complexity involved in the process is O (n). The frequency resolution is poor in the first stage. It is somehow better as stage increases. At each stage the frequency resolution increases by a factor of two.

5. 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 Fig. 3. As an example D = 6 is chosen for reference.

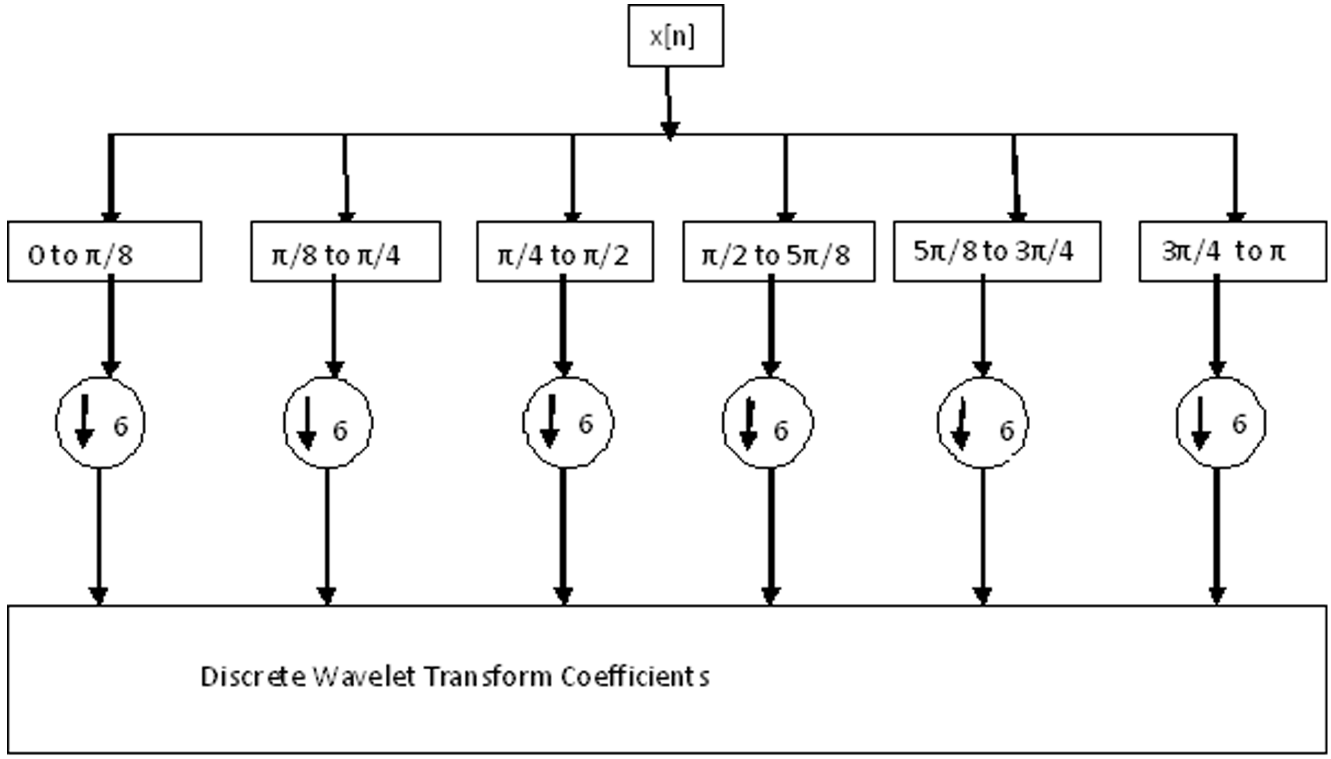

Figure 3: Discrete Wavelet Transform using Multiband Wavelet Analysis

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

It is clear from the above figure that the entire decomposition requires only six filters. The output is down sampled by a factor of six. Table.1 compares the Multiband Wavelet Analysis with conventional Multiresolution Wavelet Analysis.

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. But as stages increase the reduction becomes a positive number which means there is lesser and lesser number of filters used than in conventional Multi Resolution Wavelet Analysis. Since the number of filters does not grow as O (n) it is beneficial.

6. 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.

Figure 4: Input to the Multi Band Wavelet Analysis System

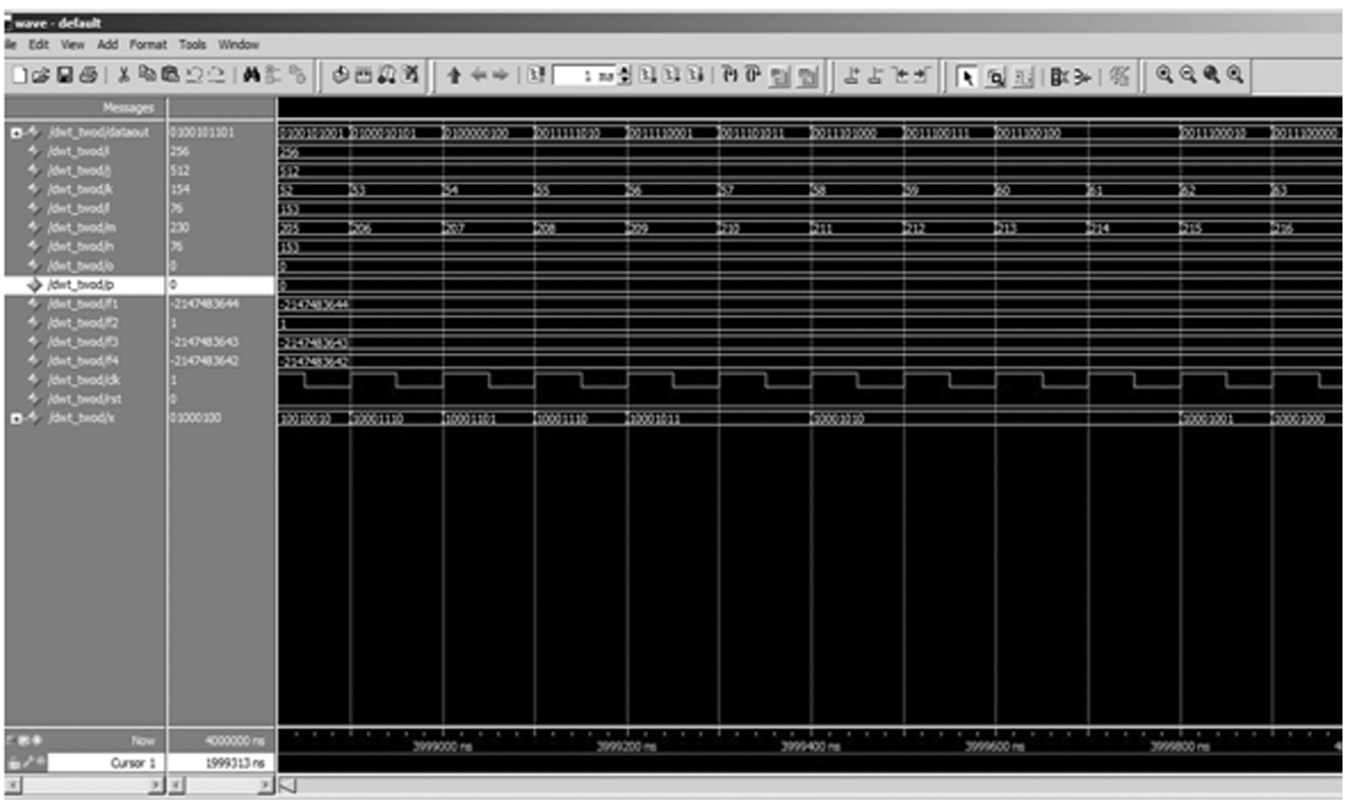

Figure 5: Simulation result of Multiband Wavelet Analysis System

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. 4.

The simulation result using Modelsim tool is shown in Fig.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 Fig.6.

The down sampled image is one of the subband images shown in Fig.7. The sub band images are small in size. All the subband images can be interpolated, filtered and processed to reconstruct the image.

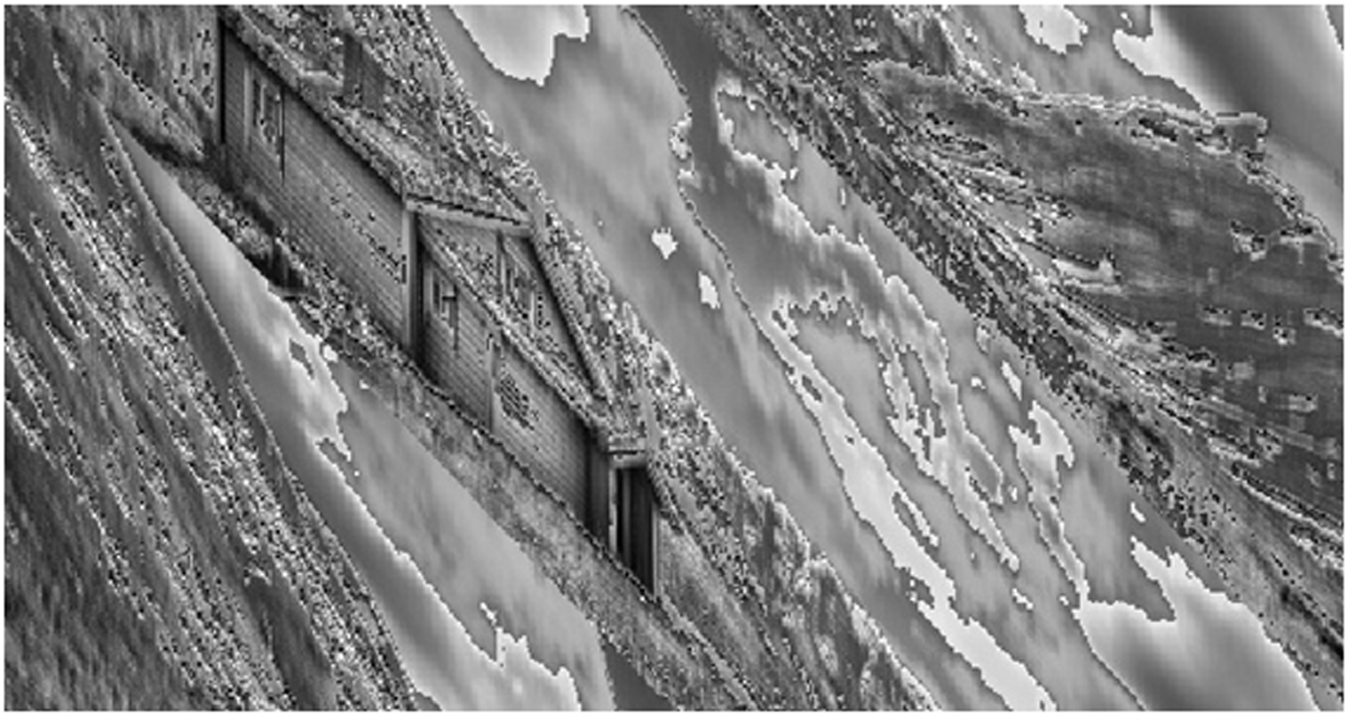

Figure 6: Output of Multiband Wavelet Analysis

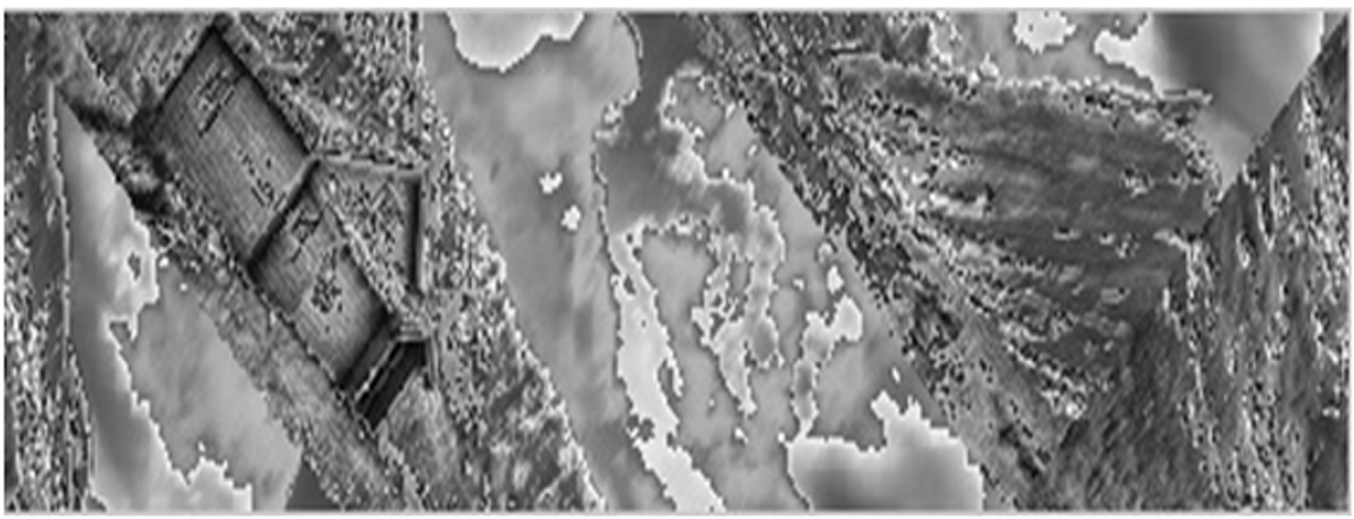

Figure 7: Sampled output of Multiband Wavelet Analysis

7. 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 frequency resolution of the output image by a large factor. Hence the sub band image occupies less space.

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