Analysis of Wavelets Based Compression in 1D Signals, 2D and 3D Images

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Abstract— *This paper deals with a analysis and study of denoising of one dimensional voice signal and also compression and decomposition of two dimensional and three dimensional images using wavelets. Analysis of image and data compression are rapidly used in field of Medical data analysis, Telemedicine, ECG analysis, Texture analysis etc. The analysis is based on transform of signal and image using discrete wavelet transform (DWT) algorithm. The performance of this algorithm is better achieved for wavelet based compression of signals and images. A simulation result shows the technique of DWT which provides sufficient high compression ratio.*

Keywords— compression, DWT, decomposition, de-noising, wavelets.

I. INTRODUCTION

First fundamental wavelets developed around 1980s, some of them are Haar wavelet, Shannon wavelet, Daubechiesetc which needs the Fourier transform. It can be used for infinite or periodic signals. Its application plays a role in identifying pure frequency, renoising signal and breakdown points and compressing. In second generation of wavelet transform, for geometrical applications, to maintain the time frequency localization, lifting scheme concept is used which replaces the Fourier analysis. Its application plays a role in geographical data analysis, lossy data compression. In third generation wavelets transform is nothing but a DWT which is typically a 2D wavelet transform used for multi-resolution and for feature characterization based on the structure of image. While next generation provides better PSNR, lossless, error free and advanced multilevel resolution. These wavelets have good efficiency and better performance. Its application plays a role in frequency localization, feature extraction, seismic analysis. The simulation results of denoised signal and compressed images of 2D and 3D wavelet transform are analyzed in this paper.

1.1 Wavelet Transform

Wavelet is originated from the French word ondelettes. A wavelet is a small signal which does not have a regular shape. The shape of wavelet is to represent the different details or resolution and the location of wavelet represents the location of events in time. It has the orthogonality property. The basic idea behind the wavelets is that the function gives the time and frequency localization and can provide a high frequency resolution at low frequency and high time resolution at high frequency. Using single function called mother wavelet, the other function are obtained by changing the size of function or scaling and translating. The scaling and translating parameters are related to each other because the scaling of basis function is narrow; the translation step is small and vice versa. There are different kinds of wavelets are available. We have to choose the suitable wavelet based on the application. To decompose and to reconstruct a signal or image, wavelet transform is used. In this wavelet transform, the decimation is used at transmitter side to remove some details and interpolation is used at receiver side to recover original details. A wavelet function Ψ(t) has two main properties, (1)That is, the function is oscillatory or has wavy appearance.

$$\int_{-\infty}^{0} \Psi(t)d(t) = 0$$

(2)That is, the most of the energy in Ψ(t) is confined to a finite duration.

$$\int_{-\infty}^{0} |\Psi(t)|^2 d(t) < \infty$$

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1.2 Discrete Wavelet Transform

In data compression, if the sampled functions have discrete time and frequency then wavelet transform used is so called Discrete Wavelet Transform (DWT). This technique is based on sub-band coding algorithm. Compression is based on the approximation of regular signal components using the filter coefficients and detailed coefficients.

"Approximation" coefficients

$$W_{\Phi}(j_0,k)=\frac{1}{\sqrt{M}}\sum_x f(x)\,\varphi_{j_0,k}(x)$$

"Detail" coefficients

$$W_{\Psi}(j,k)=\frac{1}{\sqrt{M}}\sum_x f(x)\,\psi_{j,k}(x)$$

The steps of the compression algorithm based on DWT are described below:

1. Decompose

Choose a wavelet; choose a level N. Compute the wavelet. Decompose the signals at level N.

2. Threshold detail coefficients

For each level from 1 to N, a threshold is selected and hard thresholding is applied to the detail coefficients.

3. Reconstruct

Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

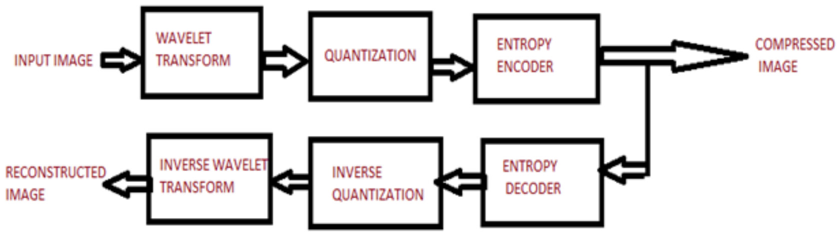
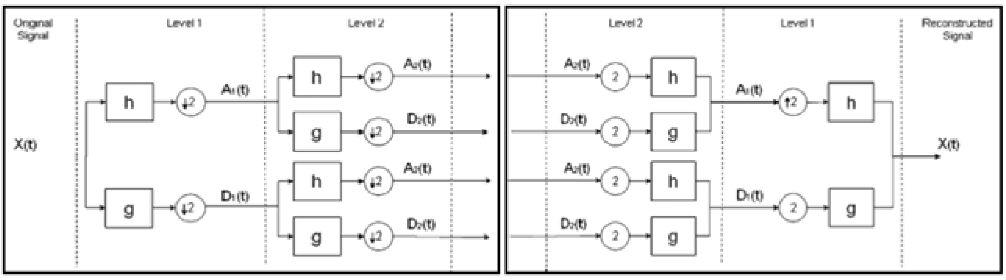


FIG 1: STRUCTURE OF WAVELET TRANSFORM BASED COMPRESSION

While decomposing a signal, we can get a very fine resolution at frequency domain. Individual frequency component, does not give temporal resolution. An image can be translated and scaled into sum of wavelet function in the wavelet transform concept. Using DWT techniques, the different dimensional wavelets are denoised and decomposed which are to be analyzed here.

II. ONE DIMENSIONAL WAVELETS

One dimensional signal are decomposed into component wavelets and reconstruct a original signal using one dimensional DWT is implemented using a low pass and high pass filters. The approximation of signal is provided by low pass filter which is linked with scaling function.



(1) **(2)**

FIG 2.1: (1) DECOMPOSITION, (2) RECONSTRUCTION

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The approximation of signal is provided by low pass filter which is linked with scaling function. The detail lost in approximating the signal is provided by high pass filter which is linked with wavelet function. The sequence of low pass and high pass filter banks are used for decomposition of 1D signal. The down sampling is used for decomposition and up sampling is deployed for reconstruction. The original signal is split into low frequency and high frequency signal that it sent to respective filter. Then it is decimated by factor 2 at level 1 in decomposition stage. A low frequency filter component consists of most of the required information compared with high pass filter. In level 2, again low frequency filter component is sent to low pass filter and high pass filter and again get decimated by factor 2. Based on our need and application, this is repeated for certain stages to decompose signal. At the same time that level 2 output is sent to up sampler in level 3 and the original signal are obtained after filtering. Usually, the down sampling is done after filtering while up sampling is done before filtering. The different wavelets such as Haar wavelet, Poisson wavelet, Shannon wavelet etc. are used for decomposition.

2.1 Denoising of signal

The signal or images are mostly affected due to unwanted interruption called noise during transmission. This leads to poor performance and the efficiency will be reduced. So the noise will be removed by the process called denoising without affecting the quality of signal. Denosing is performed using bandpass filter with cut off frequency which is traditional techniques that only remove the noise from the band of the signal. To avoid this problem, many numbers of techniques are introduced. The algorithm used for signal to remove noise will also be used for images. The wavelet based noise removal techniques provide a denoised signal with better quality.

2.2 Simulation results

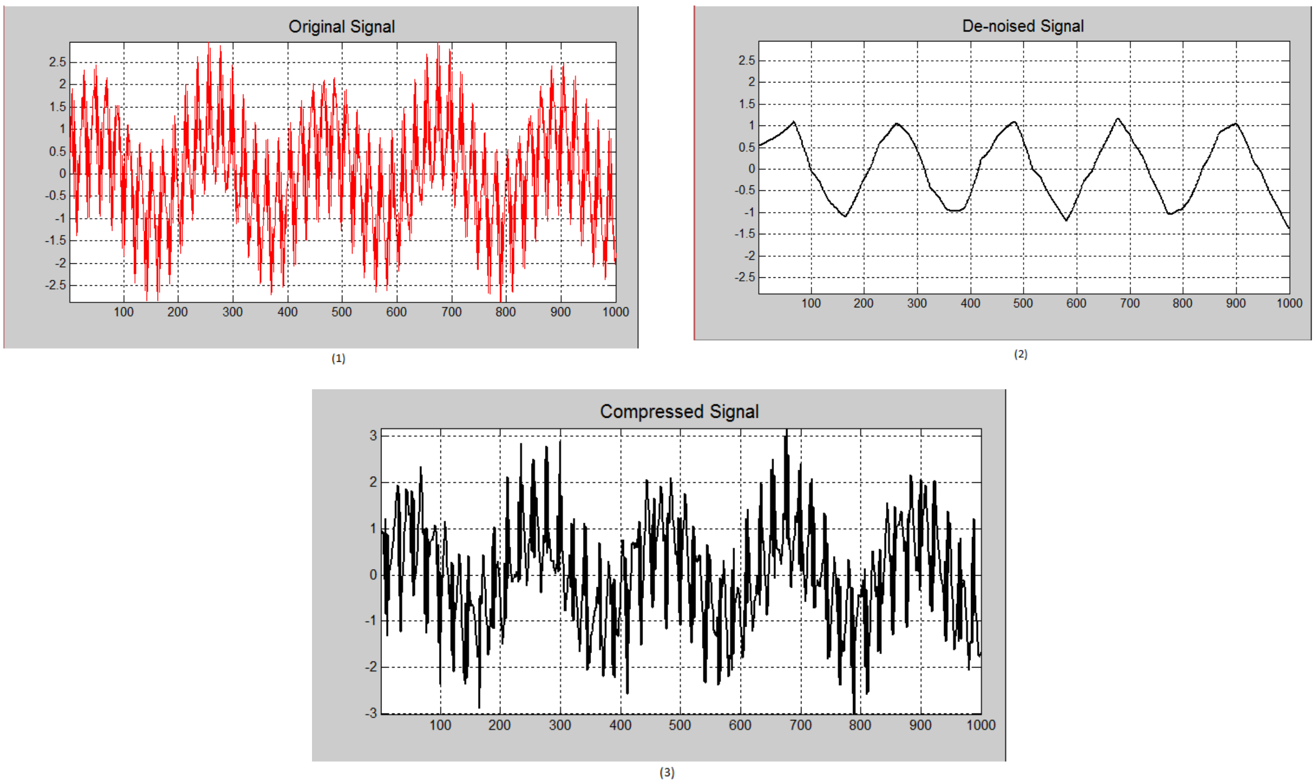

FIG 2.2: (1) ORIGINAL SIGNAL, (2) DENOISED SIGNAL, (3) COMPRESSED SIGNAL

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III. TWO DIMENSIONAL WAVELETS

Wavelets used for 2D image decomposition and reconstruction are 2D wavelets that is used for image processing applications. For higher dimensional wavelets, other than DWT the multi resolution analysis can be used. The product of 1D function is nothing but the 2D wavelets. For decomposition structure, the filter structure and filter coefficients are needed. The filter coefficients are termed as approximation coefficients and detailed coefficients are computed as

$$f_{k,l}^{j} = \int_{-\infty}^{\infty} 2^{j}\,\phi\left(2^{j}x - k,\, 2^{j}y - l\right) f(x, y)\, dx\, dy$$

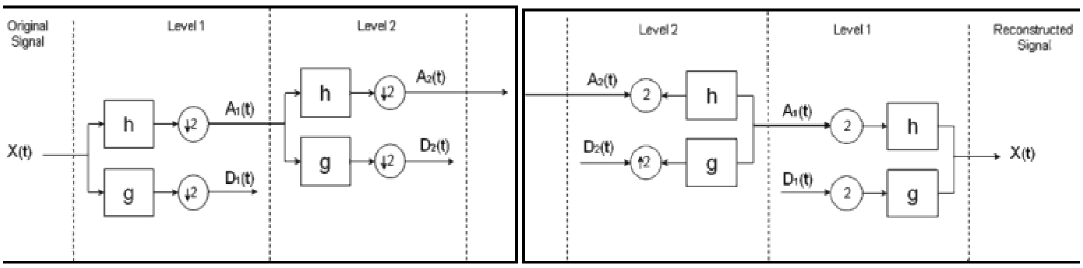
$$d_{k,l}^{(S)\,j} = \int_{-\infty}^{\infty} 2^{j}\,\psi^{(S)}\left(2^{j}x - k,\, 2^{j}y - l\right) f(x, y)\, dx\, dy,$$

The reconstruction values are,

$$f_{k,l}^{j} = \sum_{n,m} h_{m-2k,n-2l}\, f_{m,n}^{j+1} \text{ and } d_{k,l}^{(S)\,j} = \sum_{n,m} g_{m-2k,n-2l}^{(S)}\, f_{m,n}^{j+1},$$

$$f_{k,l}^{j+1} = \sum_{n,m} h_{m-2k,n-2l}\, f_{m,n}^{j} + \sum_{n,m} g_{m-2k,n-2l}^{(I)}\, d_{m,n}^{(I)\,j} + \sum_{n,m} g_{m-2k,n-2l}^{(II)}\, d_{m,n}^{(II)\,j} + \sum_{n,m} g_{m-2k,n-2l}^{(III)}\, d_{m,n}^{(III)\,j}.$$

3.1. Decomposition and reconstruction of 2D image

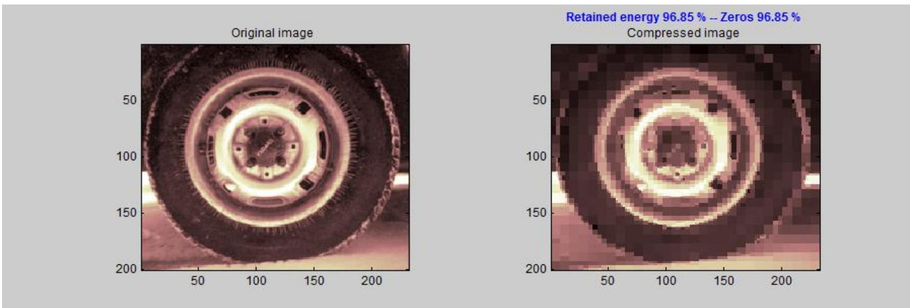


(1) (2)

FIG 3.1: (1) DECOMPOSITION, (2) RECONSTRUCTION

The original signal is split into low frequency and high frequency signal that it sent to respective filter. Then it is decimated by factor 2 at level 1 in decomposition stage. A low frequency filter component consists of most of the required information compared with high pass filter. In level 2, again low frequency filter component and high frequency components is sent to set of low pass filter and high pass filter and again get decimated by factor 2. Based on our need and application, this is repeated for certain stages to decompose signal. At the same time that level 2 output is sent to upsampler in level 3 and the original signal are obtained after filtering. Usually, the down sampling is done after filtering while upsampling is done before filtering. The stages are increased according to our need.

3.2. Simulation results



(1) (2)

FIG 3.2: (1) ORIGINAL IMAGE (2) COMPRESSED IMAGE

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IV. THREE DIMENSIONAL WAVELETS

The wavelet function allows the scaling and translation of functions based on the needs. The basis function of wavelet is obtained from scaled and dilated resolution of mother wavelet. There are three techniques available in analyzing wavelets. They are continuous wavelet transform, discrete wavelet transform and multi resolution analysis. Using a translation parameter, the convolution of X(t) and time shifted wavelet function is said to be continuous wavelet transform. If the time and scaled function discrete then the discrete wavelet transform is used. The multi resolution analysis provides a tool to adapt signal resolution to only relevant details for a particular task. For decomposition and reconstruction, the scaling function and wavelet function is used.

4.1 Decomposition and reconstruction of 3D image

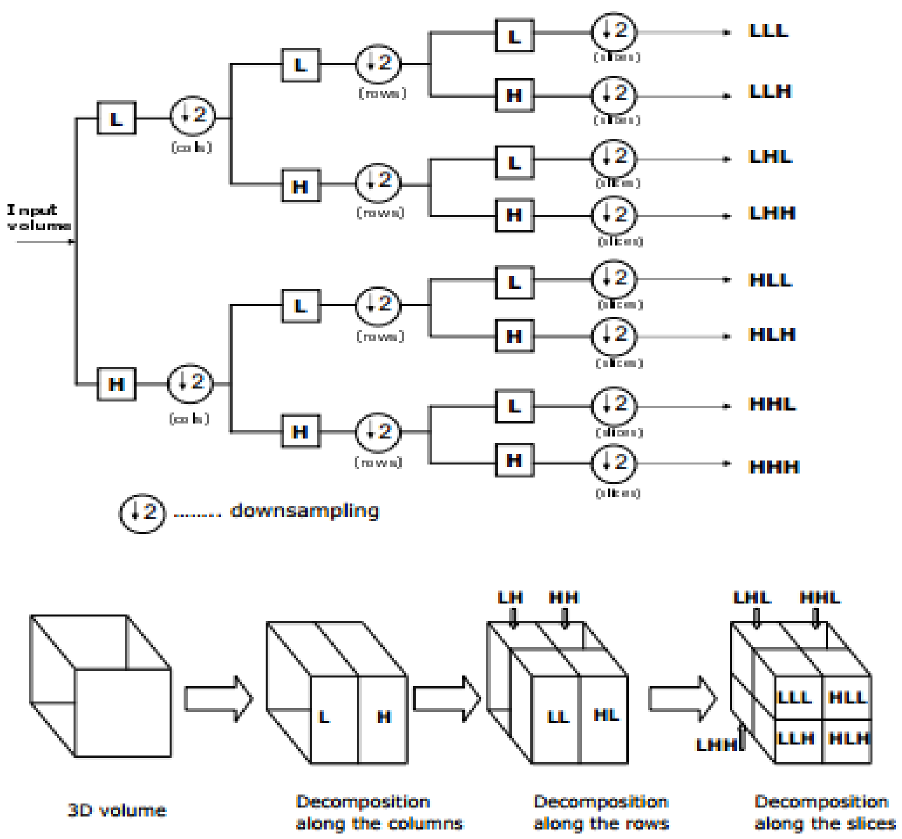

FIG 4.1 THE DECOMPOSITION TREE OF THE THREE-DIMENSIONAL VOLUME DECOMPOSITION USING DISCRETE WAVELET TRANSFORM FOR COLUMNS ROWS AND SLICES PRODUCING 8 SUB VOLUMES IN THE FIRST DECOMPOSITION STAGE

The decomposition process can be applied for multi-dimensional signals also as same as 3D. The separable products of 1-D wavelets by successively applying a 1-D analyzing wavelet in three spatial directions(x, y, z) are used to construct 3D wavelets. The X dimensions of volume are filtered at first to obtain the low pass image and high pass image. Then in Y dimension LH filtered to get a 4 decomposed sub volumes LL, LH, HL, HH. Then the eight sub volumes LLL,LLH,LHL,LHH,HLL,HLH,HHL,HHH are obtained by using 4 sub volumes in Z dimension. The removal noise components are major task here. De-noising is a procedure to recover a signal that has been corrupted by noise. After discrete wavelet decomposition the resulting coefficients can be modified to eliminate undesirable signal components.

4.2 Simulation results

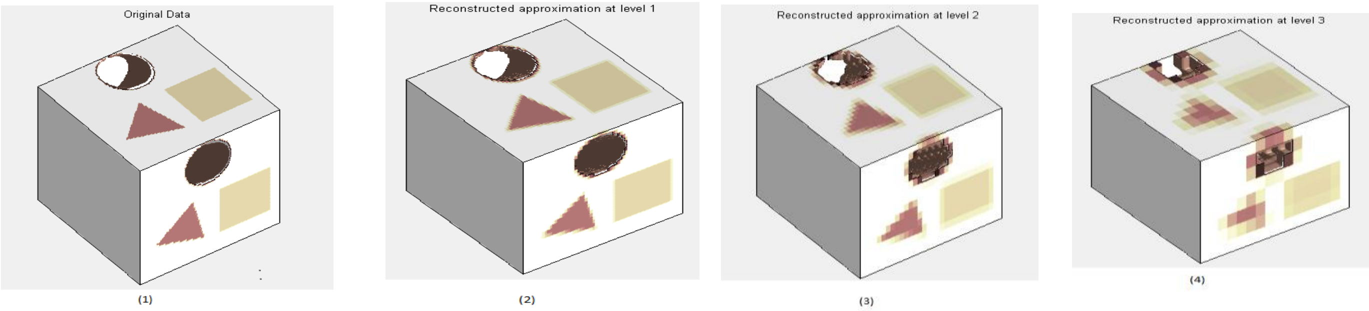

FIG 4.2 (1) ORIGINAL IMAGE, (2) RECONSTRUCTED IMAGE LEVEL1, (3) RECONSTRUCTED IMAGE LEVEL2, (4) RECONSTRUCTED IMAGE LEVEL3

V. CONCLUSION

The analysis of these different dimensional wavelets concludes that wavelets based compression technique is very useful to achieve signal with high compression with no loss of original signal or image and also with better performance with good image quality. It finds application in field such as medical data analysis, scientific research area, and engineering. Wavelets are better suited for time limited data. Using multi wavelets also it will achieve better performance.

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