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Review of Wavelet Transform and its Application in Different Compression Technique

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ABSTRACT

Wavelet Transform is an emerging tool to solve the problems related to Mathematics, Physics and Engineering. In this paper we review and discuss the advantages of Wavelet transform in comparison of Fourier Transform for the study of signal analysis. Wavelet transforms is the improved version of Fourier Transform. The main difference between them is that wavelets are well localized in both time and frequency domain whereas Fourier Transform is only localized in frequency domain. The discretely sampled form of wavelet transform which is called discrete wavelet transform is used in the study of data compression so that one can modify, encode a source of data in digital form that it occupies fewer bits than the original. This will consume less space on the disk and reduce transmission time when such information is communicated over a distance. Further the Wavelet based data compression technique is applied for the study of compression of various data signals such as image, audio, video, seismic and biomedical signals. In this paper we have reviewed about the data compression technique using wavelet transform in different type of signals.

Introduction

In 1982, Jean Morlet initiated the concept of Wavelet Transform. Wavelet Transform first time introduced for the seismic signal analysis[6]. A well known mathematical tool known as Fourier Transform, introduced in 19th century by the French mathematician J. Fourier, is generally used to transform any time domain signal into the frequency domain signal. That is, If whatever a signal is measuring, is a function of time, Fourier Transform provides the frequency component of that signal. A frequency spectrum of a signal shows that what frequency components exist in that given signal. A frequency spectrum of the signal sometimes be more useful because the information, that cannot be detected in time domain signal, canbe easily seen in frequency domain signal. For examples, In case of ECG signals.For the analysis of ECG signals or many other medical signals, the frequency information is more beneficial to diagnose the pathological conditions that might be hidden in time domain signal[11].

But the frequency spectrum of the signal that is obtained by the Fourier Transform, is applicable only for the study of stationary signals because it only provides that what frequencies are there in the signal. It does not tell Which frequency component exists at which time in the entire signal. In stationary signals all frequency components exist all times. But when the frequency of the signal changes with respect to time, as in case of non stationary signal, Fourier transform fails to explain that type of signals. This is the major drawback of Fourier transform.

It is clear from the above discussion that Fourier transform is not suitable for the signals having time varying frequency. To resolve this drawback, in 1946, Dennis Gabor introduced the Short Time Fourier Transform or Fast Fourier Transform. It is also known as windowed Fourier Transform. The Short Time Fourier Transform (STFT) is differ from the Fourier transform in the sense that in STFT the entire non stationary signal is divided in small segments in such a manner that each segment is considered as a separate stationary signal. To execute this idea Gabor introduced a window function, which is located at the beginning of the signal. The width of the window is such that it is equivalent to stationary segment of the non stationary signal. Now the multiplication of each segment with the window function is taken and this product is considered as a individual signal. The Fourier Transform of this product gives the information that which frequency components are there in that particular segment.This exercise is continued till the end of the signal by shifting the window with a fix time interval. Hence we can say that the STFT of the signal is the multiplication of the signal with the window function.

With the help of the following figure it can be understand better

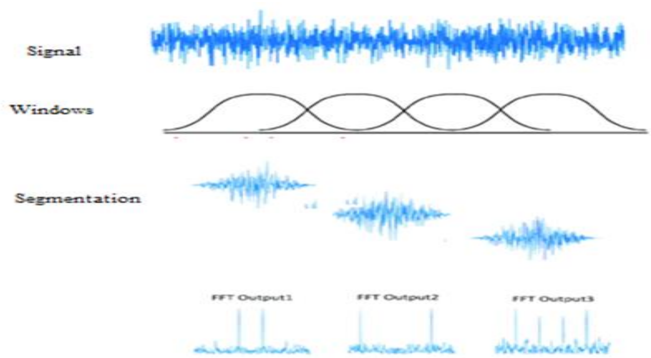

Fig. 1. Short time Fourier Transform

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From the discussion till now, it is found that STFT is a better tool for the time frequency representation (TFR) of anon stationary signal. A drawback of STFT is encountered that is the resolution problem of STFT. In STFT, once we choose the width of time window. It will remain same throughout the analysis for all frequencies. If the window is taken narrower, the time resolution will be betterbut poorer the frequency resolution. But if the window is taken wider, the frequency resolution will be better but poorer the time resolution Thus the STFT only analysis that which frequency components exists during which period of time. It does not tell what is the frequency at a particular time.

In STFT we get the frequency, time and magnitude in the same graph.

AT WHAT TIME THE FREQUENCY COMPONENT OCCUR, FT cannot tell.

Multi Resolution Analysis

Due to the time and frequency resolution problems in STFT, an alternative approach is adopted, called Multi resolution analysis. All the spectral component of a signal cannot be resolved by the constant width of the window as in case of STFT. Multi Resolution analysis is the concept in which the width of the window is changed for every single spectral component. MRA analyzes the signal at different frequencies by different resolution by changing the width of window.

Wavelet Transform

The continuous wavelet transform is an another approach to encounter the resolution problem in STFT. The only difference between CWT and STFT is the width of the window. In CWT, the width of the window is changed according to the every single spectral component under consideration. It is the most important feature of CWT over STFT.

Mathematically the Continuous Wavelet transform is defined as

$$CWT = \int f(t)\psi_{ab}(t)dt$$

$$Where \psi_{ab}(t) = \frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right) \; a, b \in R, a \neq 0$$

This equation shows how a function $f(t)$ is decomposed into a set of basis functions $\psi_{a,b}(t)$ called the wavelets.

Here there are two variables in the transformed function

$a \rightarrow scaling\ parameter\ measures\ degree\ of\ compression$

$b \rightarrow translation\ parameter\ measures\ the\ location\ of\ the\ window$

Discrete Wavelet Transformation (DWT)

Discrete wavelet transform is a wavelet transform for which the wavelets are discretely sampled. CWT can not practically computed by the analytical equations. It is thus important to discretize the transform. In discrete wavelet transform, the filters of different cut of frequency are applied on the signal to study the signal at different frequencies or scale. If the signal is passed through the series of high pass filter then it is used to analyze the high frequency data and if passed through low pass filter, then it is used to study low frequency components. In some of the samples can be removed from the signal. if the subsampling of the signal is done by the Nyquist's sampling rate, then the original continuous time signal can be reconstructed by the discretely sampled data.

Application of Wavelets

Wavelet transform is a powerful tool that is used in a number of fields. Some applications of wavelet transform are as follows

Digital signal processing
Data compression
Radar
Magnetic resonance imaging
Seismic signal detection
Analysis of biomedical images like ECG Signals.
Speech recognition
Fingerprint verification
Astronomy

Wavelets in Data Compression

Here in this section, we have reviewed the work done on image compression through Haar and Daubechies wavelets.

Haar wavelets: Haar wavelets are first proposed in 1909 by Alfred Haar. It is the first and simplest form of wavelets. Haar wavelets are real and orthogonal in nature.Lossy and lossless, both type of compression can be done by wavelet transform.

NidhiSethi et al.[12] discussed the image compression by Haar wavelet transform. The algorithm applied separates the high frequency and low frequency components of image matrix by passing through band pass filters. The process is implemented in 2D way, first along the row and then along the column. Three iterations of this transformation is attended. Further the decomposed image is quantized. Quantization is the process through which the image becomes more compressible. The compression of the image is evaluated in terms of parameters like PSNR (peak signal to noise ratio), MSE (mean square error).

Sulaiman khan et al.[13] has presented the haar wavelet transform, discrete cosine transform and run length encoding scheme for compression with high compression rates. In these techniques the image is converted into half of its length. It is well known that the image data is represented in matrix form of pixel values. The image is broken into 8x8 blocks and Haar transformation is applied on one 8x8 image block. Haar transformation is simply the process of differencing and averaging of the image matrix along the rows and along the columns. Finally the compression is successfully achieved with no signicant loss of information.

AnujBhardwaj et al.[14] applied the MFHWT (Modified Fast Haar Wavelet Transform) Scheme for the image compression and found better results than other methods. Haarwavelet transform and Fast haar transform involves the addition, differentiation and division by 2 or √2. But in case of MFHWT, four nodes are considered in place of two nodes as in case of Haar wavelet transform and Fast haar transform it makes the calculation easier and decreases the calculation time for overall compression work. The reconstruction of images is also good as other averaging and differencing method. Hence MFHWT has a great potential in the field of image compression.

Daubechies wavelets: Daubechies wavelets are represented by the notation dbN, where N is the order of wavelet.

D. Ravichandran et al[15] has discussed the wavelet based image compression on the biomedical images like X-ray, MRI images and CT imaging etc. In the case presented here, Daubechies wavelets are used for multilevel decomposition of the medical images. The quantization is done by global thresholding. The quantized image is further encoded by the Huffman encoding scheme. The researcher used the MATLAB wavelet toolbox for the purpose and identifyupto which level the decomposition can be possible in case of medical images without significant loss of information.

Emmanuel et al.[] has discussed the comparative studies of compression through orthogonal Daubechies and coiflet wavelets on the fingerprint print images taken by the fingerprint database of the National Institute of standards and technology, USA. Orthogonal Daubechies and Coiflet wavelets are applied to fingerprint data upto level three. Level dependentthresholding is applied to all the three level separately. The decomposed images are analyzed at all the levels percentage of different parameters like number of zeroes (NZ%) and retained energy (RE%).

Literature Review Related To DWT

P. Prashant et al.[1] has discussed the image compression by discrete wavelet transformation,discrete cosine transform and Huffman encoding scheme. A comparision of hybrid image compression algorithm with the DWT and DCT algorithm, applied on several images like X ray, lena, babra and other medical images, is discussed in this paper. The results were compared in terms of PSNR in terms of compression ratio. Finally the hybrid image compressed technique is found much better than DWT & DCT techniques.

AmitaRakshit et al.[2] has presented the image compression and decompression by DCT, DWT and hybrid (DCT+DWT) transform by considering several images as input. DCT compression technique involves the discarding of higher frequency component, divided the image into 8x8 blocks, DCT coefficients are measured for each block then quantized, coded and transmittedwhereas discrete wavelet transform performs multiresolution analysis. In wavelet transform the decomposed image consists of two parts- approximation and detailed part of the image. The approximation parts is further considered for compression. The hybrid (DWT+DCT) transform performs the advantages of both DWT and DCT such that it reduce the storage size of image with higher compression ratio.

Othman O. Khalifa et al.[3] has dicussed the application of wavelet compression on an audio signal using Daubechies family of wavelets. The lossy compression technique in which the mask is applied on all the audio signals that are imperceptible to human auditory system.The wavelet compression scheme is incomparable in terms of compression ratio with many other good compression techniques. In addition it is also found that using wavelets, the compression ratio can be easily vary in a particular range while other compression techniques has fixed compression ratio.

Deepanshu et al. (2016)[4] presented the compression algorithm on various digital images. In this paper they applied various wavelets of wavelet familieson two different biomedical images, MRI images of liver and shoulder, for experiment. The algorithm that is applied for compression is SPIHT and EZT. SPIHT algorithm is initiated for optimal progressive transmission and compression. EZT encoding is a lossy image compression technique. In this algorithm, if there is an insignificant DWT coefficients having value zero or nearly zero in the lowest frequencysubband at the root node, then its all decedents would be zero. It makes a tree of zeros in the lowest frequency subbandand if this tree is explored upto the corresponding spatial coefficients in the next higher frequency subband, there is a great probability that there would be one or more subtrees would be zero, known as zero tree.

A. El Boustani[5] has discussed the wavelet transform based compression system on the synthetic aperture radar(SAR) data. The raw synthetic aperture radar (SAR) contains the large amount of data to downlink at the ground station. The ground station can receive the data with the limited bandwidth. So it is necessary to reduce the collected data from moving plateform. Five orthonormal wavelet bases including Haar wavelet is used for this purpose. The purpose to study the effect of wavelet based technique on SAR became successful.

M. Siffuzzaman[6] in this paper discuss the advantages of wavelet transform over the Fourier transform for the analysis of non stationary signals. The researcher also discuss about the various applications of wavelets in different fields including physics, digital signal processing, data compression, smoothing and image denoising, analysis of ECG signals, fingerprint verification, DNA and protein analysis etc. Data compression, fingerprint verification and storing electronically isdicussed in detail. Data compression is discussed by considering the average and difference of the sequence of numbers which represents a signal. For fingerprint compression, FBI used Daubechiesbiorthogonal spline wavelets. The name of compression method is '*The Wavelet scalar Quantization Gray scale Fingerprint Image compression Algorithm*'.

Yacai Dong et al.[7] presents the application of wavelet transform in denoising MCG-signals using SQUID as a detecting device. Squid is a highly sophisticated equipment detect and diagnose the heart disease. In this paper the method used for MCG-signal denoising is wavelet threshold denoising method. In this method the orthogonal wavelet transform focuses the energy of signal on some big wavelet coefficient and distribute the noise to the smaller amplitude value of coefficients. The later has reduced to zero using threshold method.

Xiao-Gui Miao et al.[8] has discussed the application of wavelet transform in detecting seismic data signals. Any seismic signal can be explained in terms of its travel time, frequency and coherent noise. The orthogonal wavelet functions are undesirable for seismic signals so the Morlet wavelet, a non orthogonalwavelet is applied for the remarkable suppressing of coherent noise in seismic signal. The applied wavelet function has the property to localize the characteristics of input signal and remove the ground roll noise in the reflection and refraction survey data of seismic signals.

I. Provaznik et al.[9] in this paper introduces the wavelet transform in various application of cardiology. It is well known from the basic studies of wavelet transform that it is used for non stationary signal. ECG signals are also non stationary signals. In this paper the researcher deals with the two areas of time frequency ECG signal. First the time frequency decomposed signal analysis that classify all the patterns of ECG signal and secondworks on the filtering of some wavelet coefficients includes denoise and data compression both.

Rekha D. Patil[10] has discussed reversible image watermarking using LWT and airthmatic coding. Reversible watermarking is a technique which is capable to hide the information and restores the original data without any distortion. Lifting wavelet transform divides the original image into separate blocks and integer wavelet transform is taken for all the blocks. These blocks are then embedded into high frequency coefficients.

Conclusion

In this paper, we reviewed a number of papers where the application of wavelet transform is applied in various domain of engineering and technology. Wavelet transform is widely used in the field of compression of any type of data like images, audio, video or any digital signal. Haar, biorthogonal and symlet wavelets are used for medical image compression. Compression of medical images based on wavelet transform is useful for telemedicine application. In telemedicine application, compressed medical images are transmitted through telecommunication networks. In future, through this study, medical image compression technique is implemented using wavelet transform.

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