A Review: Various Wavelet Based Image Compression Techniques

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ABSTRACT   *Image compression is one of the most visible applications of wavelets. A Wavelet is a finite energy signal defined over specific interval of time. Wavelets can be combined, using a "reverse, shift, multiply and sum" technique called convolution. Wavelets often give a better signal representation using Multiresolution analysis, with balanced resolution at any time and frequency. Wavelets are localized in both time and frequency whereas the standard Fourier transform is only localized in frequency. Here in this paper we examined and compared various wavelet based techniques such as continuous wavelet Transform, Discrete Wavelet Transform, Wavelet Packets and Fast Wavelet transform. Wavelet packet method is a generalization of wavelet decomposition that offers a richer signal analysis. The Discrete Wavelet Transform analyzes the signal at different frequency bands with different resolutions by decomposing the signal into an approximation and detail information. Image coded by DWT do not have the problem of blocking artifacts which the DCT approach may suffer.Mallet Algorithm based fast wavelet analysis makes the use of extension of a given finite-length signal and removes the border effects due to convolution.*

INTRODUCTION

Data compression is the technique to reduce the redundancies in order to decrease data storage requirements and hence communication costs. Data is represented as a combination of information and redundancy. Information is the portion of data that must be preserved permanently in its original form in order to correctly interpret the meaning or purpose of the data. The redundancy can be of two types: spatial redundancy and subjective redundancy. In plane areas where adjacent picture element (pixel) have almost same values means that the pixel values are highly correlated is called spatial redundancy. Subjective redundancy, which is determined by properties of human visual system(HVS)[3].Main principles of image compression is to remove Redundancy and Irrelevancy Reduction. So image compression can be achieved by removing Redundancy and Irrelevancy from images. Data compression can be defined as a method that takes an input data D and generates a shorter representation of the data c(D) with less number of bits as compared to that of D. The reverse process is called decompression, which takes the compressed data c(D) and generates or reconstructs the data D"[2] as shown in Figure 1. Sometimes the compression (coding) and decompression (decoding) systems together are called a "CODEC"

Figure 1: CODEC

The reconstructed data D" could be identical to the original data D or it could be an approximation of the original data D, depending on the reconstruction requirements. If the reconstructed data D" is an exact replica of the original data D, the algorithm applied to compress D and decompress c(D) is lossless. On the other hand, the algorithms are lossy when D" is not an exact replica of D. Hence as far as the reversibility of the original data is concerned.

Image compression can be lossy or lossless , Usually lossless data compression techniques are applied on text data or scientific data .Lossless compression achieves compression by reducing the entropy of the original data, while avoiding introducing distortions into it. As a result, the original data can be

perfectly recovered from the compressed bits. Examples of lossless compression technologies include Run-length coding, Huffman coding and Arithmetic coding, etc.[1] Lossy Compression means loss of information Often this is because the compression scheme completely discards redundant and irrelevant information.Lossy compression can achieve much higher compression but Lossless compression can achieve low compression. In this paper we discuss various Techniques of image compression.

2. RELATED WORK, ISSUES AND POSSIBLE SOLUTIONS

[1] has presented a quality constrained compression algorithm based on Discrete Wavelet Transform (DWT) is proposed. [2] presents a the IMAP block and IMAQ block of MATLAB was used to analyse and study the results of Image Compression using DCT and varying co-efficients for compression were developed to show the resulting image and error image from the original images. [3] Examines a set of wavelet functions (wavelets) for implementation in a still image compression system and to highlight the benefit of this transform relating to today's methods. The paper discusses important features of wavelet transform in compression of still images, including the extent to which the quality of image is degraded by the process of wavelet compression and decompression. Image quality is measured objectively, using peak signal-to-noise ratio or picture quality scale, and subjectively, using perceived image quality. The effects of different wavelet functions, image contents and compression ratios are assessed. A comparison with a discrete-cosine- transform-based compression system is given.[4] A Min-Image was originally created to test one type of wavelet and the additional functionality was added to Image to support other wavelet types, and the EZW coding algorithm was implemented to achieve better compression.[5] This paper aims to determine the best wavelet to compress the still image at a particular decomposition level using wavelet transforms and wavelet packet transforms. Compression Ratio (CR) and Energy Ratio (ER) is determined for different wavelets at different threshold values ranging from 5 to 100 for decomposition level 2. [6] Here a low complex 2D image compression method using wavelets as the basis functions and the approach to measure the quality of the compressed image are presented. The particular wavelet chosen and used here is the simplest wavelet form namely the Haar Wavelet. The 2D discrete wavelet transform (DWT) has been applied and the detail matrices from the information matrix of the image have been estimated. The reconstructed image is synthesized using the estimated detail matrices and information matrix provided by the Wavelet transform.[7] A review of the fundamentals of image compression based on wavelet is given here also discussed important features of wavelet transform in compression of images. In this paper evaluated and compared three different wavelet families i.e. Daubechies, Coiflets, Bi-
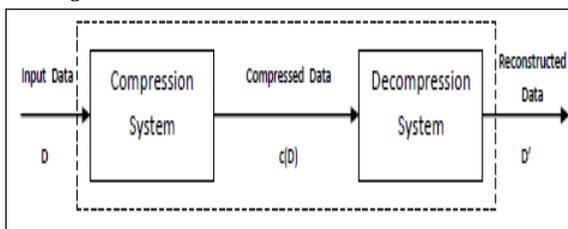
orthogonal. Image quality is measured, objectively using peak signal-to-noise ratio, Compression Ratio and subjectively using visual image quality.[8] analyze the performance of orthogonal and Biorthogonal wavelet filters for image compression on variety of test images. The test images are of different size and resolution. The compression performance is measured, objectively peak signal to noise ratio and subjectively visual quality of image and it is found that Biorthogonal wavelets outperform the orthogonal ones in both the criteria.[9] The paper discusses important features of wavelet transform in compression of still images, including the extent to which the quality of image is degraded by the process of wavelet compression and decompression and checks the results in terms of image quality metrics PSNR and also computes compression ratios at different level of decompositions of DWT. Haar, Symlets and Biorthogonal wavelets have been applied to an image and results have been compared in the form of qualitative and quantitative analysis in terms of PSNR values and compression ratios.[10]. This paper compares Compression Ratio, Energy Ratio, Mean Square Error, and Peak Signal to Noise Ratio at different Threshold values for decomposition level 2 both for DWT and WPT.

2. WAVELETS

A wavelet is a wave-like oscillation with an amplitude that begins at zero, increases, and then decreases back to zero. This is also known as one complete cycle it not only has an oscillating wavelike characteristic but also has the ability to allow simultaneous time and frequency analysis with a flexible mathematical foundation. As Compare to wavelets with sine waves, which are the basis of Fourier analysis. Sinusoids do not have limited duration they extend from minus to plus infinity. And where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric.

Fourier analysis consists of breaking up a signal into sine waves of various frequencies. Similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet. Just looking at pictures of wavelets and sine waves, we can see that signals with sharp changes might be better analyzed with an irregular wavelet than with a smooth sinusoid, just as some foods are better handled with a fork than
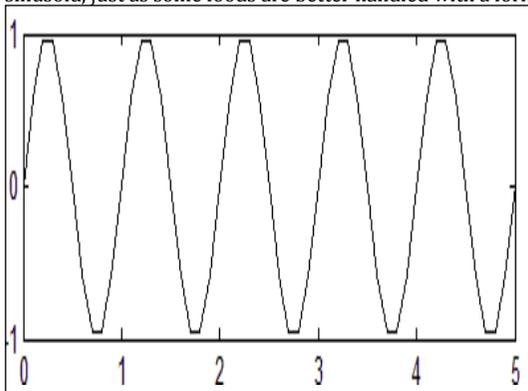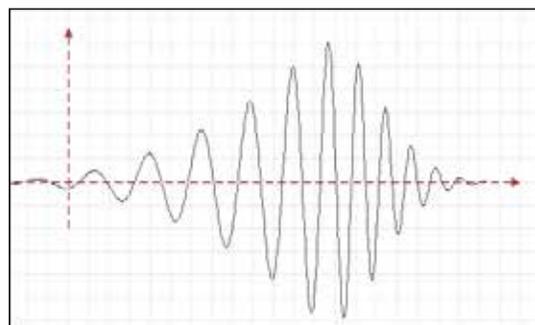

Figure1: A Wave



Figure2: Wavele2.1 WAVELET BASED TECHNIQUES:

1. CONTINOUS WAVELET TRANSFORM

Mathematically, the process of Fourier analysis is represented by the Fourier transform:

which is the sum over all time of the signal f(t) multiplied by a complex exponential.

Similarly, the continuous wavelet transform (CWT) is defined as the sum over all time of the signal multiplied by scaled, shifted versions of the wavelet function:
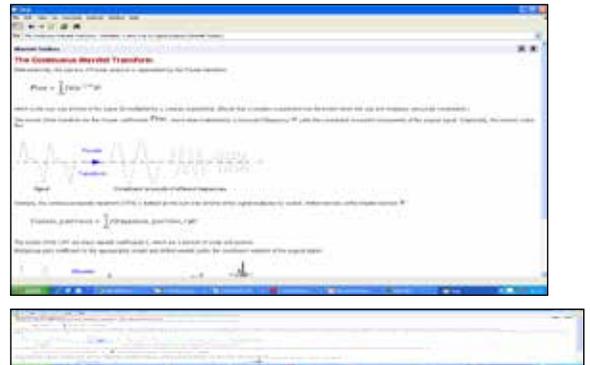
The results of the CWT are many wavelet coefficients C, which are a function of scale and position. Multiplying each coefficient by the appropriately scaled and shifted wavelet yields the constituent wavelets of the original signal

2.DWT: Discrete wavelet transforms

The discrete wavelet transform (DWT) refers to wavelet transforms for which the wavelets are discretely sampled. A transform which localizes a function both in space and scaling and has some desirable properties compared to the Fourier transform. The transform is based on a wavelet matrix, which can be computed more quickly than the analogous Fourier matrix.

The discrete wavelet transform (DWT) is a mathematical tool that has aroused great interest in the field of image processing due to its nice features. Some of these characteristics are: 1) It allows image multi resolution representation in a natural way because more wavelet subbands are used to progressively enlarge the low frequency subbands; 2) It supports wavelet coefficients analysis in both space and frequency domains, thus the interpretation of the coefficients is not constrained to its frequency behavior and we can perform better analysis for image vision and segmentation; and 3) For natural images, the DWT achieves high compactness of energy in the lower frequency subbands, which is extremely useful in applications such as image compression. The introduction of the DWT made it possible to improve some specific applications of image processing by replacing the existing tools with this new mathematical transform. The JPEG 2000 standard proposes a wavelet transform stage since it offers better rate/distortion (R/D) performance than the traditional discrete cosine transform (DCT).

Advantages over DCT:

1) Compared with DCT, the coefficients of DWT are well localized in not only the frequency, but also the spatial domains. This frequency-spatial localization property is highly desired for image compression [11].
2) DWT decomposes an image into spatially correlated subbands that hold different frequency components of the image. Each subband can be thought as a subset of the image with a different spatial resolution such that the visual quality and the compression ratio of the compressed image can be controlled by adjusting the distortions of different subbands [12].
3) Images coded by DWT do not have the problem of block artifacts which the DCT approach may suffer [13].
4) Compared with DCT, DWT has lower computation complexity, O(N) instead of O(NlogN) [14].

3. WAVELET PACKETS

The wavelet packet method is a generalization of wavelet decomposition that offers a richer signal analysis.Wavelet packet atoms are waveforms indexed by three naturally interpreted parameters: position, scale (as in wavelet decomposition), and frequency[5].

3.1 From Wavelets to Wavelet Packets: Decomposing the Details

In the orthogonal wavelet decomposition procedure, the generic step splits the approximation coefficients into two parts. After splitting we obtain a vector of approximation coefficients and a vector of detail coefficients, both at a coarser scale. The information lost between two successive approximations is captured in the detail coefficients. Then the next step consists of splitting the new approximation coefficient vector; successive details are never reanalyzed.In the corresponding wavelet packet situation, each detail coefficient vector is also decomposed into two parts using the same approach as in approximation vector splitting.
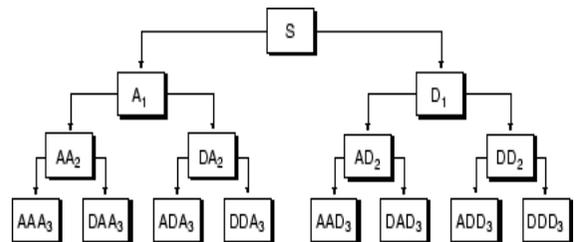
3.2 Wavelet Packet Spectrum

The spectral analysis of wide-sense stationary signals using the Fourier transform is well-established. For nonstationary signals, there exist local Fourier methods such as the short-time Fourier transform (STFT). See Short-Time Fourier Transform for a brief description.

Because wavelets are localized in time and frequency, it is possible to use wavelet-based counterparts to the STFT for the time-frequency analysis of nonstationary signals.. However, a potential drawback of using the CWT is that it is computationally expensive.

The discrete wavelet transform (DWT) permits a time-frequency decomposition of the input signal, but the degree of frequency resolution in the DWT is typically considered too coarse for practical time-frequency analysis.

As a compromise between the DWT- and CWT-based techniques, wavelet packets provide a computationally-efficient alternative with sufficient frequency resolution. In the wavelet packet framework, compression and de-noising ideas are exactly the same as those developed in the wavelet framework. The only difference is that wavelet packets offer a more complex and flexible analysis, because in wavelet packet analysis, the details as well as the approximations are split.

In figure : Aproximation and Detail coefficient

A single wavelet packet decomposition gives a lot of bases from which you can look for the best representation with respect to

a design objective. This can be done by finding the "best tree" based on an entropy criterion.

Compression are interesting applications of wavelet packet analysis. The wavelet packet de-compression procedure involves four steps:

1. Decomposition
2. Computation of the best tree
3. Thresholding of wavelet packet coefficients
4. Reconstruction

1. FAST WAVELET TRANSFORM

In 1988, Mallat produced a fast wavelet decomposition and reconstruction algorithm [Mal89]. The Mallat algorithm for discrete wavelet transform (DWT) is, in fact, a classical scheme in the signal processing community, known as a two-channel subband coder using conjugate quadrature filters or quadrature mirror filters (QMFs).

The decomposition algorithm starts with signal s, next calculates the coordinates of A1 and D1, and then those of A2 andD2, and so on.

The reconstruction algorithm called the inverse discrete wavelet transform (IDWT) starts from the coordinates of AJand DJ, next calculates the coordinates of AJ–1, and then using the coordinates of AJ–1 and DJ–1 calculates those of AJ–2, and so on.

In order to understand the multiresolution analysis concept based on Mallat's algorithm it is very useful to represent the wavelet transform as a pyramid, as shown in figure 12. The basis of the pyramid is the original image, with C columns and R rows.

Figure 1: Pyramidal representation of Mallat's wavelet decomposition algorithm.

Given a signal s of length N, the DWT consists of $\log_2 N$ stages at most. Starting from s, the first step produces two sets of coefficients: approximation coefficients cA_1, and detail coefficients cD_1. These vectors are obtained by convolving s with the low-pass filter Lo_D for approximation, and with the high-pass filter Hi_D for detail, followed by dyadic decimation.

The length of each filter is equal to $2n$. If N = length (s), the signals F and G are of length $N + 2n - 1$, and then the coefficients cA_1 and cD_1 are of length

$$\text{floor}\left(\frac{(N-1)}{2} + n\right)$$

The next step splits the approximation coefficients cA_1 in two parts using the same scheme, replacing s by cA_1 and producing cA_2 and cD_2, and so on.

Classically, the DWT is defined for sequences with length of some power of 2, and different ways of extending samples of

other sizes are needed. Methods for extending the signal include zero-padding, smooth padding, periodic extension, andboundary value replication (symmetrization). The basic algorithm for the DWT is not limited to dyadic length and is based on a simple scheme: convolution and downsampling . As usual, when a convolution is performed on finite-length signals, border distortions arise. To Remove these border effects , Fast Wavelet Transform was introduced. This algorithm is a method for the extension of a given finite-length signal .

5. Conclusion

In this paper various wavelet based techniques are discussed we conclude that DWT removes the problem of blocking artifact and it has various advantages over DCT .It allows good localization both in time and spatial frequency domain and also it has various advantages over Fourier Transform. Continuous wavelet transform (CWT) is used in the analysis of sinusoidal time varying signals. As compare to Wavelet packets CWT is difficult to implement and the information that has been picked up may overlap and results in redundancy. Wavelet Packets provide a computationally-efficient alternative with sufficient frequency resolution. And last Fast Wavelet Transform using Mallat Algorithm overcome the problems of border distortions and large processing times that occur in DWT technique.

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