A Survey of Wavelet Compression Methods

G.Arunalatha, S.Sarathraj, K.Manodurga

Abstract— Wavelets provide a powerful and remarkably flexible set of tools for handling fundamental problems in science and engineering, such as audio de-noising, signal compression, object detection and fingerprint compression, image de-noising, image enhancement, image recognition, diagnostic heart trouble and speech recognition, to name a few[1][2]. This paper proposes a comprehensive survey on different Wavelet Transform techniques.

Index Terms— Compression, Wavelet and Wavelet Transform.

1 Introduction

Image compression is very important for efficient transmission and storage of images. Demand for communication of multimedia data through the telecommunications network and accessing the multimedia data through Internet is growing explosively. With the use of digital cameras, requirements for storage, manipulation, and transfer of digital images, has grown explosively. These image files can be very large and occupy a lot of memory. A gray scale image that is 256 x 256 pixels have 65, 536 elements to store and a typical 640 x 480 color image have nearly a million. Downloading of these files from internet is time consuming task. Image data comprise of a significant portion of the multimedia data and they occupy the major portion of the communication bandwidth for multimedia communication. Therefore development of efficient techniques for image compression has become quite necessary. A common characteristic of most images is that the neighboring pixels are highly correlated and therefore contain highly redundant information. The basic objective of image compression is to find an image representation in which pixels are less correlated. The two fundamental principles used in image compression are redundancy and irrelevancy. Redundancy removes redundancy from the signal source and irrelevancy omits pixel values which are not noticeable by human eye. JPEG and JPEG 2000 are two important techniques used for image compression. Work on international standards for image compression started in the after 1970s with the CCITT (currently ITU-T) need to standardize binary image compression algorithms for Group 3 facsimile communications. Image compression standards bring about many benefits, such as: easier exchange of image files between different devices and applications; reuse of existing hardware and software for a wide array of products; existence of benchmarks and reference data sets for new and alternative.

Image compression may be lossy or lossless. Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art, or comics. This is because lossy compression methods, especially when used at low bit rates, introduce compression artifacts. Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate. The lossy compression that produces imperceptible differences may be called visually lossless.

Image compression model shown here consists of a Transformer, quantizer and encoder.

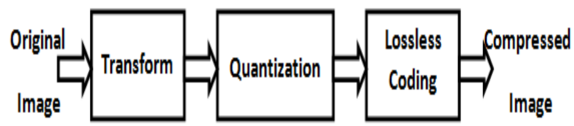

Fig.1 (a). Image Compression model

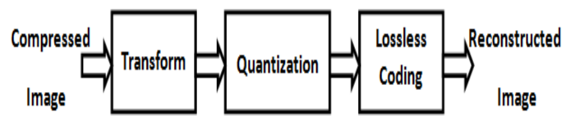

Fig.1 (b). Image Decompression model

2 Wavelet Transform

A wavelet is a wave-like oscillation with an amplitude that starts out at zero(0), increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismographer heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. Wavelets can be combined, using a "reverse, shift, multiply and sum" technique called convolution, with portions of an unknown signal to extract information from the unknown signal.

Wavelet transform are classified into discrete wavelet transforms (DWTs) and continuous wavelet transforms (CWTs). Note that both DWT and CWT are continuous-time (analog) transforms. They can be used to represent continuous-time (analog) signals. CWTs operate over every possible scale and translation whereas DWTs use a specific subset of scale and translation values or representation grid.

There are a large number of wavelet transforms each suitable for different applications. For a full list see list of wavelet-related transforms but the common ones are listed below:

1. Continuous wavelet transform (CWT)
2. Discrete wavelet transform (DWT)
3. Fast wavelet transform (FWT)
4. Lifting scheme & Generalized Lifting Scheme
5. Stationary wavelet transform (SWT)

6. Fractional Fourier transform (FRFT)
7. Fractional wavelet transform (FRWT)

2.1 Continuous Wavelet Transforms (Continuous Shift and Scale Parameters)

In continuous wavelet transforms, a given signal of finite energy is projected on a continuous family of frequency bands (or similar subspaces of the L^p function space $L^2(\mathbf{R})$). For instance the signal may be represented on every frequency band of the form [f, $2f$] for all positive frequencies $f > 0$. Then, the original signal can be reconstructed by a suitable integration over all the resulting frequency components.

The frequency bands or subspaces (sub-bands) are scaled versions of a subspace at scale 1. This subspace in turn is in most situations generated by the shifts of one generating function ψ in $L^2(\mathbf{R})$, the *mother wavelet*.

2.2 Discrete Wavelet Transforms (Discrete Shift and Scale Parameters)

It is computationally impossible to analyze a signal using all wavelet coefficients, so one may wonder if it is sufficient to pick a discrete subset of the upper half-plane to be able to reconstruct a signal from the corresponding wavelet coefficients. One such system is the affine system for some real parameters $a > 1$, $b > 0$. The corresponding discrete subset of the half-plane consists of all the points (a^m, $na^m b$) with m, n in Z.

2.3 Multi-Resolution Discrete Wavelet Transforms

In any discretised wavelet transform, there are only a finite number of wavelet coefficients for each bounded rectangular region in the upper half-plane. Still, each coefficient requires the evaluation of an integral. To avoid this numerical complexity, one needs one auxiliary function, the father wavelet φ in $L^2(R)$. Further, one has to restrict to be an integer. A typical choice is $a = 2$ and $b = 1$. The most famous pair of father and mother wavelets is the Daubechies 4-tap wavelet.

2.4 Mother Wavelet

For practical applications, and for efficiency reasons, one prefers continuously differentiable functions with compact support as mother (prototype) wavelet (functions). However, to satisfy analytical requirements (in the continuous WT) and in general for theoretical reasons, one chooses the wavelet functions from a subspace of the space $L^1(\mathbb{R}) \cap L^2(\mathbb{R})$.

2.5 Comparisons with Fourier Transform (Continuous-Time)

The wavelet transform is often compared with the Fourier transform, in which signals are represented as a sum of sinusoids. The main difference is that wavelets are localized in both time and frequency whereas the standard Fourier transform is only localized in frequency. The Short-time Fourier transform (STFT) is more similar to the wavelet transform, in that it is also time and frequency localized, but there are issues with the frequency / time resolution trade-off. Wavelets often give a better signal representation using Multi-resolution analysis, with balanced resolution at any time and frequency.

The discrete wavelet transform is also less computationally complex, taking O(N) time as compared to O(N log N) for the fast Fourier transform. This computational advantage is not inherent to the transform, but reflects the choice of a logarithmic division of frequency, in contrast to the equally spaced frequency divisions of the FFT (Fast Fourier Transform) which uses the same basis functions as DFT (Discrete Fourier Transform). It is also important to note that this complexity only applies when the filter size has no relation to the signal size. A wavelet without compact support such as the Shannon wavelet would require $O(N^2)$. (For instance, a logarithmic Fourier Transform also exists with O(N) complexity, but the original signal must be sampled logarithmically in time, which is only useful for certain types of signals.).

3 Wavelet Transform Techniques

3.1 Modified Wavelet Packet

Modified Wavelet Packet [3] Scheme uses a fixed decomposition structure and matched to the statistics of fingerprint image. It also decorrelates the image pixels. Both hard and soft thresholding schemes are used to make procedure fast and efficient. When compare to OWT, E-BBB, WSQ & JPEG techniques it gives high compression ratio and high reconstruction image quality with low computational cost.

3.2 Adaptive Wavelet Packet

2D convolution decimation algorithm with factorized non-separable 2D filters [4]:
It is 4-times faster than standard convolution decimation then the Cost function that takes into account the cost of coding, the output levels of quantizers, and the cost of coding the significant map. The Context based entropy coder is used to condition the probability of significant of a given pixel on the probability of its neighbors using a space filling curve. This technique Performed on large class of textured images and Evaluation included quantitative figures also subjective visual appearance. Wavelet packet coder tends to create artifacts at the same locations (at strong edges) as the wavelet coder does with similar intensity Finally the Artifacts created by wavelet packets affects more pixels than those created by wavelets.

3.3 Multiwavelet And Multiwavelet Packets

Wavelet Transform require filters that combine a number of desirable properties such as orthogonality and symmetry because the design possibilities for wavelets are limited because they cannot simultaneously posses all of the desirable properties. Some limitations of wavelets are overcome by Multiwavelets. Multiwavelets offers more design options and able to combine several desirable transform features but in Previous

Multiwavelet image compression mostly faller short of the performance. Multiwavelet packets are the combination of both Multiwavelet Transform and Quantization methods so that this technique is superior to current wavelet filters [5].

Multiwavelet Packets = Multiwavelet transform + Quantization methods

3.4 Binary Space Partitioning And Geometric Wavelets

Segmentation based image compression technique based on Binary Space Partitioning (BSP) and Geometric Wavelets (GW)[6]. Using the BSP technique, image is segmented recursively into number of segments until an exit criterion is met and tree is formed with all these segments and GW is used to remove insignificant nodes present in the tree. This technique outperform when compare to various wavelet based and transform based image compression techniques.

3.5 Projection Based And Adaptive Reversible Integer Wavelet Transform

Reversible Integer Wavelet Transforms [7] are increasingly popular in lossless image compression and the projection based technique is presented for decreasing the first order entropy of transform coefficient and improving the lossless compression performance of reversible IWT. This technique is used to predict a WT coefficient as a linear combination of other WT coefficients. It is superior to other lossless compression's performance.

3.6 DPCM transform with WT

DPCM [8] is used in this compression algorithm and the different image is transformed by integer wavelet at the same time we can get bit stream by lossless SPIHT algorithm. Corresponding reversible transform is used to reconstruct the image. It is very easy to implement in both hardware and the software. It is an effective LIC method.

3.7 Wavelet Scalar Quantization (WSQ)

Wavelet Scalar Quantization (WSQ)[9] is an image compression technique. Which has long tradition as an effective encoding scheme and it is superior to JPEG and similar performance when compared to JPEG2000.

3.8 Hybrid- NRCT

Contourlet Transform (CT) can efficiently capture curved and oriented geometrical structures in images. The drawback of CT is 4/3 redundancy in its oversampling ration. This can be eliminated by using Non-Redundant CT (NRCT). NRCT is applicable for critical sampling and perfect reconstruction and is suitable for tracking and efficiently coding oriented structure in images such as texture of ridges in fingerprint images. NRCT is easily compatible with WT. NRCT with WT is called Hybrid NRCT[10]. Hybrid NRCT based algorithm outperforms both wavelet based and Contourlet based compression especially at lower bit rates.

3.9 Discrete Wavelet Transformation (DWT) and Tucker Decomposition (TD)

Compression of Hyper-Spectral Images (HSIs) has recently become very attractive issues for remote sensing application because of their volumetric data. An efficient method for hyper-spectral image compression algorithm based on Discrete Wavelet Transformation (DWT) and Tucker Decomposition (TD) (DWT-TD)[11], exploits both the spectral and the spatial information in the images. Core idea is to apply TP on the DWT coefficients of spectral bands of HSIs. This technique use DWT to effectively separate HSIs into different sub-images and TD to efficiently compact the energy of sub-images. It gives the better performance when compare to real HSIs and well known compression techniques. Impact of compression HSIs on the supervised classification and lineal un-mixing. This technique reducing the size of 3D tensors computed from four wavelet sub-images of the spectral bands of HSIs.

3.10 Fractional Random Wavelet Transform (FrRnWT)

FrRnWT [12] inherits the excellent mathematical properties of wavelet transform and fractional random transform. The possible applications for FrRnWT are in biometrics, image compression, image transmission, transient signal processing, etc. This technique is peculiarly suitable for securing fingerprints during communication and transmission over insecure channel.

4 Conclusion

Wavelets provide a powerful and remarkably flexible set of tools for handling fundamental problems in science and engineering, such as audio de-noising, signal compression, object detection and fingerprint compression, image de-noising, image enhancement, image recognition, diagnostic heart trouble and speech recognition, to name a few. In this paper we have discussed the techniques which are based on Wavelet Transform.

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- *G.Arunalatha is Assistant Professor in Department of Computer Science and Engineering(CSE) in Perunthalaivar Kamarajar Institute of Engineering and Technology (PKIET), Karaikal, Puducherry, E-mail: arunalathamaha@gmail.com*
- *S.Sarathraj is currently pursuing B.Tech Final Year (CSE)in PKIET, Karaikal, Puducherry,E-mail: sarathrajkss@gmail.com*
- *K.Manodurga is currently pursuing B.Tech Final Year (CSE)in PKIET, Karaikal, Puducherry,E-mail:manodurga84@yahoo.com*

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