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Wavelet-Based Image Compression and its Application

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ABSTRACT
Image compression addresses the problem of reducing the amount of data required to represent a digital image. The objective of this paper is to evaluate set of wavelet for image compression. Image compression using wavelet transforms result in an improved compression ratio. Wavelet transformation is the technique that provides both spatial and frequency domain information. These properties of wavelet transform greatly help in identification and selection of significant and non –significant coefficients amongst the wavelet coefficients. DWT (Discrete Wavelet Transform) represent image as a sum of wavelet function (Wavelet) on different resolution levels. So, the basis of wavelet transform can be composed of function that satisfies requirement of multi resolution analysis. The choice of wavelet function for image compression depends on the image application and content of image. A review of the fundamental of image discussed important features of wavelet transform in compression of images. It also reduces the amount of time required for image to be sent over Internet or download from web page. After this process, whenever the original image is required, then the compressed image is decompressed to construct the original image or an approximation of it.

KEYWORDS: Bandwidths; Long Term Evolution (LTE); Image compression; Retain energy

1. Introduction

The rapid development of high performance computing and communication has opened up tremendous opportunity for various computer – based applications with image and video communication capability.the data compression become the only solution to overcome this.Image compression is the representation of an image in digital form with as few bits as possible while maintaining an acceptable level of image quality. The basic measure of the performance of a compression algorithm is the compression ratio, which is defined by the ratio between original data size and compressed data size. Higher compression ratios will produce lower image quality and vice versa is also true.

The initial focus was on the development of analog methods for reducing video transmission

bandwidth, called Bandwidth Compression. However, with the development of digital computers and advancement of integrated circuits, the interest shifted from analog to digital compression approaches. Image compression is the natural technology for handling the increased spatial resolutions of today's imaging sensors and evolving broadcast television standards. Image Compression plays a major role in many important applications that include television conferencing, remote sensing (the use of satellite imagery for weather and other earth resource applications), document and medical imaging, facsimile transmission (FAX), and the control of remotely piloted vehicles in military and space etc. applications [5]. Compressing an image is different than compressing binary data. General-purpose compression programs can be used to compress images, but the results are less than optimal. This is because images have certain statistical properties. Also, some of the finer details in the image can be sacrificed for saving a little more bandwidth or storage space.

2. Image compression methodology

There are different methods for image compression but every method has three basic steps transformation, quantization or thresholding, and minimization of number of bits to represent the image i.e. compressed image (encoding) (**Fig. 1**).

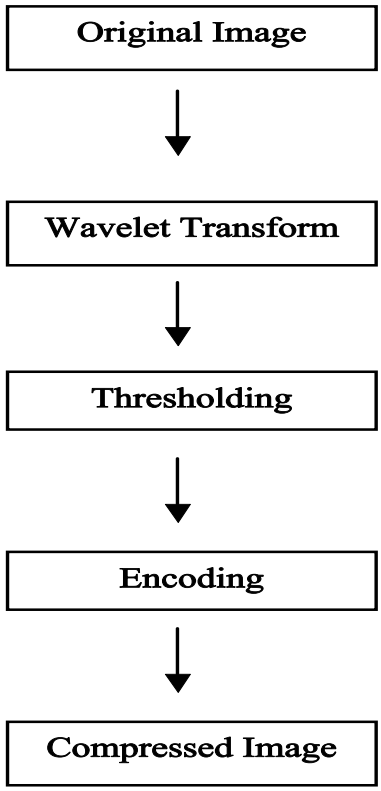

Fig. 1 Image compression process.

There are some mathematical transformations have been invented for the sole purpose of data compression, other have been borrowed from various applications and applied to data compression. The list includes: Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Slant-Haar Transform (SHT), Walsh-Hadamard Transform (WHT), Short Fourier Transforms (SFT), and Wavelet Transform (WT).WT is used as transformation technique in image compression process. Wavelet analysis can be used to divide the information of an image into approximation coefficients and detail coefficients. The approximation coefficients show the general trend of pixel values, and detail coefficients show the Horizontal (H), Vertical (V), and Diagonal (D) details or changes of the image. If these details are very small, they can be set to zero without significantly changing the image. The value below which details are considered small enough to be set

to zero is known as threshold. The greater the number of zeros the greater the compression ratio. The amount of information retained by an image after compression and decompression is known as Retain Energy (RE). If the RE is 100% the compression is known as Lossless as image can be reconstructed exactly. This occurs only when the threshold value is set to zero. If there are any changes in the retain energy then the compression is known as lossy. The selection of threshold value is not an easy task [1]. For the high value of threshold the loss of information is more, and for low value of threshold loss of information is less. By considering the resultant loss of information, the selection of threshold should be low, but for the low value of the threshold there is negligible compression of data. Hence quantization factor or threshold value should be selected in such a way that it should satisfy the constraints of human visual system for better visual quality, and high compression ratio. The last phase of compression reduces the overall number of bits needed to represent the data set. An encoder further compresses the quantized values to give better overall compression. This process removes the redundancy in the form of repetitive bit patterns in the output of quantizer [1].

3. Wavelet theory

A wavelet is a waveform of effectively limited duration that has an average value of zero. Wavelets tend to be irregular and asymmetric. Wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original wavelet. Signal with sharp changes can be better analyzed with irregular wavelet than with smooth sinusoid. Wavelet Transform (WT) represents an image as a sum of wavelet functions (wavelets) with different locations and scales [2]. Wavelet transform affords wide space for image coding algorithms because of its excellent space-frequency localization characterizations. The compact supported, symmetrical and biorthogonal wavelet has linear phase, so it is applied on image compression area widely.

3.1 Wavelet evolution

Wavelets are evolved from the very fundamental and popular Fourier transform. The principles of wavelet transform are similar to those of Fourier transform, which was first developed in 19th century. Fourier transform is used widely for signal and image processing applications. Evolution of wavelets is as follows:

(I) **Fourier analysis:** Fourier analysis is well known tool, which breaks down a signal into constituent sinusoids of different frequencies. This is a mathematical technique used to transform a signal from time-based to frequency.

(II) **Short-time Fourier analysis:** To overcome the limitation of Fourier Analysis, Dennis Gabor used Fourier Analysis to analyze a small section of the signal at a time. This technique is known as windowing the signal and Dennis Gabor's adaptation is known

as Short-Time Fourier Transform (STFT). *STFT* maps a signal into 2-dimensions (frequency and time).

(III) Advantage of *STFT* is the gain of time and frequency information. Limitation is that, only a limited amount of information could be available due to this technique and that too depending on the size of window. Some signals require varying size window for finer details in terms of time or in terms of frequency, which is not possible in *STFT*.

(IV) **Wavelet analysis:** Wavelet analysis represents a windowing technique with variable sized regions. Wavelet analysis allows the use of long time intervals where more precise low frequency information is required and short time intervals where high frequency information is required. The power and magic of wavelet is multiresolution analysis. Rather than examining the entire signal through same window different parts of wave are viewed through different sized window. High frequency parts of signal use small window to get good time resolution and low frequency parts of signal use large window to get good frequency information. Natural images are well characterized as a linear combination of energy concentrated in both frequency and space. Most of the energy of images is concentrated in low frequency information, and of the remaining high frequency components of the image, most energy is spatially concentrated around edges.

3.2 Applications of wavelet transform

Wavelet transform is being used in many areas of Image processing. Some of the commonly used applications are as follows:

I. Image processing
II. Signal processing
III. Progressive image compression (useful for low bit rate)
IV. Fingerprint verification
V. ECG (electrical activity of the heart, electrocardiograph)
VI. Speech recognization
VII. EEG (electrical activity of the brain, electroencephalograph)
VIII. De-noising a signal
IX. EMG (electrical activity of the muscles, electromyogram).
X. Computer graphics
XI. Medical imaging

3.3 Advantages of wavelet based compression

There are several advantages of Wavelets and Wavelet based compression. Here is the list of most important advantages as follows:

I. Wavelet schemes at higher compression avoid blocking artifacts.

II. Wavelets provide both time and frequency information hence giving time frequency representation of signal with variable size window.
III. Wavelets are better matched to the HVS (Human Visual System**)** characteristics.
IV. Wavelets are capable of revealing aspects like drifts, breakdown points, discontinuity, self similarity.
V. Wavelets compress a image or de-noise a signal without appreciable degradation.
VI. Wavelets results in better reconstructed image even at high compression ratio.
VII. Wavelets use fast wavelets transform i.e. DWT (from where signal passes and coefficients emerge) therefore its computation is fast.
VIII. Wavelets also provide an efficient decomposition of signals prior to compression.
IX. Wavelet compression is very efficient at low bit rates.
X. Wavelets allow multiresolution analysis. Few parts of signal to be resolved well in time and some parts of signal to be resolved well in frequency.
XI. Wavelets are irregular. So signals with sharp changes are better analyzed with irregular wavelet.
XII. Compression with wavelets is scalable as the transform process can be applied to an image as many times as wanted and hence high compression ratio can be achieved.
XIII. Wavelet based compression allows parametric gain control for image softening and sharpening.

3.4 Limitation of wavelet based compression

Wavelet compression does require more computational power than compression based on other techniques such as Discrete Cosine Transform (DCT). This is due to the reason that Wavelet Transform produces more compressed image than Discrete Cosine Transform.

4 Conclusions

A number of transform techniques exist corresponding to signals and images. Fourier transform is the older one but the limitation is the loss of time information. Short Time Fourier Transform (*STFT*) is also available for the purpose but the size of window is fixed. Wavelets are the best available transform methods due to the facility of variable sized windows. Wavelets have the ability to produce the information about time and frequency both hence giving time frequency representation of signal with variable sized window. Wavelet analysis is very powerful and extremely useful for compressing data such as images. Its power comes from its multiresolution analysis. Wavelet analysis can be seen to be far superior, in that it does not create blocking artifacts. This is because the wavelet analysis is done on the entire image rather than sections at a time. Changing the decomposition level changes the amount of detail in the decomposition. Thus, at higher decomposition levels, higher compression rates can be obtained. Very large numbers of wavelets are available for transformation including

'*Haar*', '*daubetchies*', '*Symlets*', '*Coieflets*', '*Orthogonal*', '*Biorthogonal*'.

In this dissertation, research is done on biorthogonal wavelet family. *Weighted coefficients of biorthogonal wavelet filter bior4.4 are modified to make them more energy preserving*. The reason for choosing only biorthogonal family is the availability of large range of linear phase filters in this family. Biorthogonal Wavelets provide high computational speed and excellent compression performance. The compactly supported, symmetrical and biorthogonal wavelet has linear phase, so it is applied on image compression area widely. One of the most popular set of biorthogonal filters are the Daubechies 9/7 analysis and synthesis filter.

In the proposed algorithm, *an enhanced biorthogonal filter is used for the image compression*. The results are evaluated and compared qualitatively as well as quantitatively and experimental results show that the proposed filter is better than existing filters. Thus on the basis of the above results, it is concluded that:

I. Retain energy is more in image compression using proposed filter as compared to existing biorthogonal filter.
II. Compression score is slightly high as compared to existing filter in case of global thresholding.
III. It is further concluded that results at levels 4 and 5 retain more energy as compared to other levels.

For future work, it would be interesting to modify the other wavelet filters to retain more energy and more compression score. These include finding the best thresholding strategy, finding the best wavelet for a given image, investigating other wavelet families, the use of wavelet packets and image de-noising. Till now only still images are taken into consideration, animated videos and other videos could be considered for further research. To obtain better PSNR values with more retain energy and more compression score can be considered as further research work.

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