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Improving Image Compression Using DWT

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***Abstract*— Image compression has become an important process in today's world of information exchange. Image compression helps in effective utilization of high speed network resources.The discrete wavelet transform (DWT) is a technique for converting a signal into elementary frequency components. It is widely used in image compression. Here some functions for compression of both gray scale and color images with DWT and its implementation in MATLAB have been developed. The DWT is very similar to a Fourier series , but in many ways, is much more flexible and informative. It is a tool which breaks up data into different frequency components or sub bands and then studies each component with a resolution that is matched to its scale. Unlike the Fourier series, it can be used on non-stationary transient signals with excellent results.**

***Keywords*— DWT, Image compression, Lossless compression, Lossy Compression, Quantization**

I. INTRODUCTION

Image compression is an important issue in digital image processing. The image compression is also an important issue in finding the extensive applications in many fields. Due to great innovation in display and information technology, the data storage capacity for storage of information has increased drastically. Now-a-days the high quality cameras produce high quality images. These high quality images require large amount of storage space. For such scenario, the data compression technique is applied to offer acceptable solution. Image compression is of two types lossy and lossless compression. For lossy compression technique, many standards have been developed such as JPEG [1] and JPEG 2000 [2] for still images.

The reconstructed image is not exactly same as the original image in lossy image compression technique An important development in image compression is the establishment of the JPEG 2000 standard for compression of color pictures. Using the JPEG2000 method, a 24 bit/pixel color images can be reduced to between 1 to 2 bits/pixel, without obvious visual artifacts. The DWT is an improvement over the discrete Fourier transform (DFT).Here we have computed some codes in MATLAB for compression of images using DWT. The results have been observed in the laboratory for both the compression of gray scale and color images.

II. TYPES OF IMAGE COMPRESSION

There are two types of image compression. These are :

A. *Lossless compression*
B. *Lossy compression*

A. *Lossless Compression*

A high degree of correlation exists between the neighbouring pixels in natural images. In lossless compression techniques, this statistical redundancy is exploited in such away that the entire process is reversible *i.e*. the original image is exactly recovered. There is considerable interest in lossless techniques, especially in applications which require very high fidelity reconstructed images (*e.g.* medical imaging).

B. *Lossy compression*

The lossless compression techniques usually result in a low compression ratio(typically 2 to 3). Hence, they are not employed when a high compression ratio is required. In lossy compression, the objective is to reduce the bit rate subject to some constraints on the image quality. Most lossy compression techniques can be classified into following categories - predictive coding, transform coding, wavelet/subband, vector quantization, fractal coding.

III. NEED FOR IMAGE COMPRESSION

The amount of data associated with visual information is so large that its storage would require enormous storage capacity. Although the capacities of several storage media are substantial, their access speeds are usually inversely proportional to their capacity. Typical television images generate data rates exceeding 10 million bytes per second. There are other image sources that generate even higher data rates. Storage and/or transmission of such data require large capacity and/or bandwidth, which could be very expensive. Image data compression techniques are concerned with reduction of the number of bits required to store or transmit images without any appreciable loss of information. Image transmission. teleconferencing; computer communications; and facsimile transmission. Image storage is required most commonly for educational and business documents, medical images used in patient monitoring systems, and the like. Because of their wide applications, data compression is of great importance in digital image processing.

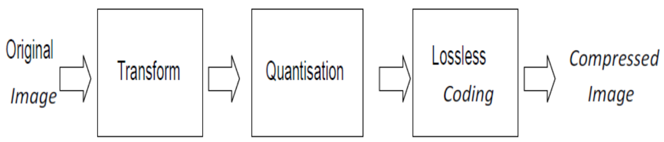

Fig1.1. Image compression system

III. DISCRETE WAVELET TRANSFORM

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A wavelet is defined as a "small wave" that has its energy concentrated in time to provide a tool for the analysis of transient, non-stationary, or time-varying phenomena. It has the oscillating Wave-like properties but also has the ability to allow simultaneous time and frequency analysis. Wavelet Transform has emerged as a powerful mathematical tool in many areas of science and engineering, more so in the field of audio and data compression.

In Fourier transform domain, we completely lose information about the localization of the features of an audio signal. Quantization error on one coefficient can affect the quality of the entire audio file. The wavelet expansion allows a more accurate local description and separation of signal characteristics. A wavelet expansion coefficient represents a component that is itself local and is easier to interpret. The Fourier basis functions have infinite support in that a single point in the Fourier domain contains information from everywhere in the signal. Wavelets, on the other hand, have compact or finite support and this enables different parts of a signal to be represented at different resolution.

Wavelets are adjustable and adaptable and can therefore by designed for adaptive systems that adjust themselves to suit the signal. Fourier Transform, however, is suitable only if the signal consists of a few stationary components. Also, the amplitude spectrum does not provide any idea how the frequency evolve with time.

All wavelets tend to zero at infinity, which is already better than the Fourier series function. Furthermore, wavelets can be made to tend to zero as fast as possible. It is this property that makes wavelets so effective in signal and audio compression.

A. *Subband Coding*

A signal is passed through a series of filters to calculate DWT.Procedure starts by passing this signal sequence through a half band digital low pass filter with impulse response h(n).Filtering of a signal is numerically equal to convolution of the tile signal with impulse response of the filter.

$$x[n]*h[n]=\sum_{k=-\infty}^{\infty} x[k].h[n-k]$$

A half band low pass filter removes all frequencies that are above half of the highest frequency in the tile signal.Then the signal is passed through high pass filter.The two filters are related to each other as

$$h[L-1-n]=(-1)^n g(n)$$

Filters satisfying this condition are known as quadrature mirror filters.After filtering half of the samples can be eliminated since the signal now has the highest frequency as half of the original frequency.The signal can therefore be subsampled by 2,simply by discarding every other sample.This consitutes 1 level of decomposition and can mathmatically be expressed as

$$Y1[n]=\sum_{k=-\infty}^{\infty} x[k]h[2n-k]$$

$$Y2[n]=\sum_{k=-\infty}^{\infty} x[k]g[2n+1-k]$$

where y1[n] and y2[n] are the outputs of low pass and high pass filters, respectively after subsampling by 2.

This decomposition halves the time resolution since only half the number of sample now characterizes the whole signal.Frequency resolution has doubled because each output has half the frequency band of the input.This process is called as sub band coding.It can be repeated further to increase the frequency resolution as shown by the filter bank.

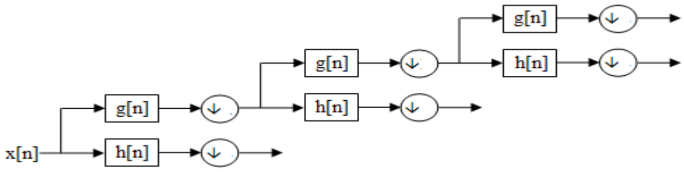

Fig2.Filter Bank

B. *Compression Steps*

- Digitize the source image into a signal s, which is a string of numbers.
- Decompose the signal into a sequence of wavelet coefficients w.
- Use threshold to modify the wavelet coefficients from w to w'.
- Use quantization to convert w' to a sequence q.
- Entropy encoding is applied to convert q into a sequence e.

Digitation

The image is digitized first.The digitized image can be characterized by its intensity levels,or scales of gray which range from 0(black) to 255(white), and its resolution, or how many pixels per square inch.

Thresholding

In certain signals, many of the wavelet coefficients are close or equal to zero.Through threshold these coefficients are modified so that the sequence of wavelet coefficients contains long strings of zeros. In hard threshold ,a threshold is selected.Any wavelet whose absolute value falls below the tolerance is set to zero with the goal to introduce many zeros without losing a great amount of detail.

Quantization

Quantization converts a sequence of floating numbers w' to a sequence of integers q.The simplest form is to round to the nearest integer.Another method is to multiply each number in w' by a constant k, and then round to the nearest integer.Quantization is called lossy because it introduces error into the process,since the conversion of w' to q is not one to one function.

Entropy Coding

With this method,a integer sequence q is changed into a shorter sequence e,with the numbers in e being 8 bit integersThe conversion is made by an entropy encoding table.Strings of zeros are coded by numbers 1 through 100,105 and 106,while the non-zero integers in q are coded by 101 through 104 and 107 through 254.

IV. DWT RESULTS

Results obtained with the matlab code[20]are shown below.Fig(3.1) shows original Lena image.Fig(3.2) to Fig(3.4) show compressed images for various threshold values.As

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threshold value increases blurring of image continues to increase.

Fig3.1 Original Lena image

Fig3.2 Compressed image for threshold value 1

Fig3.3 Compressed image for threshold value 2

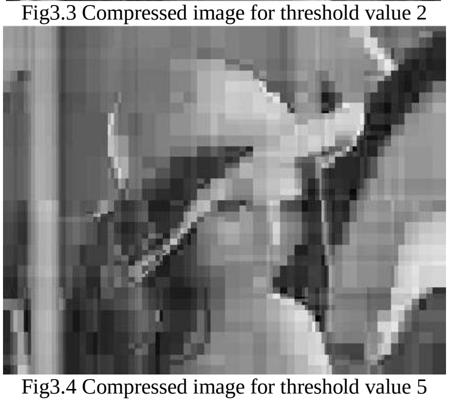

Fig3.4 Compressed image for threshold value 5

V. VARIOUS PERFORMANCE PARAMETERS

Mean Squared Error (MSE) is defined as the square of differences in the pixel values between the corresponding pixels of the two images. Fig(4.1) shows that MSE first decreases with increase in window size and then starts to increase slowly with finally attaining a constant value. Fig(4.2) plot show required for compressing image with change in window size for DWT. Fig(4.3) indicate compression ratio with change in window size for DWT based image compression technique. Compression decreases with increase in window size for DWT.

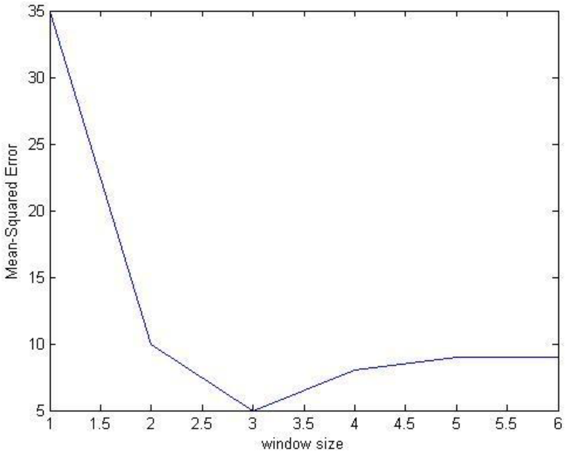

Fig4.1. mean squared error vs. Window size for DWT

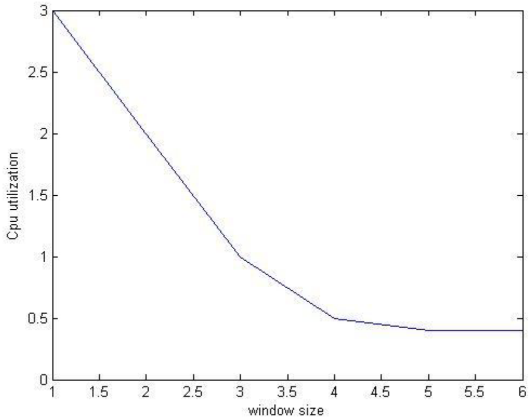

Fig4.2. cpu utilization vs. Window size for DWT

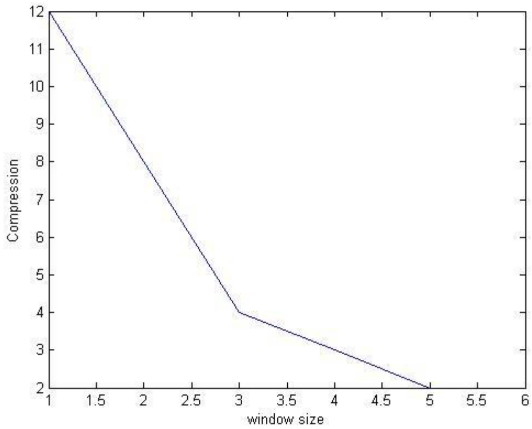

Fig4.3. compression vs. window size for DWT

VI. CONCLUSIONS

DWT is used as basis for transformation in JPEG 2000 standard. DWT provides high quality compression at low bit rates. The use of larger DWT basis functions or wavelet filters produces blurring near edges in images.

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