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Image Compression –A Comprehensive Study

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Abstract: Image Processing is latest field of research now - a - days. Image Processing is application of Signal Processing techniques 2D signal such as photograph. Image processing consists of various fields like Image Segmentation, Image Compression, Image Enhancement and many more. Image Compression is the field of Image processing which includes the compression of Images, Videos etc. This paper covers introduction, image compression schemes, wavelet theory, wavelet transform , applications of wavelets, advantages of wavelets. In this paper we are going to concentrate on wavelet applications in field of image compression and show how wavelets, a good technique for image compression.

Keywords: Image Compression, Redunancy, Wavelet , Wavelet Transform , Wavelet Filters .

I. INTRODUCTION

The most important concept of Image Compression is to reduce the irrelevancy and redundancy of image in order to store and transmit image data in efficient form .Wavelets are well known transform methods in field of Image Compression. The transformation is applied prior to storage or transmit data. However , Fourier Transform (FT) , Discrete Cosine Transform (DCT), JPEG , JPEG 2000, Fractals are also available for the purpose of transformation[1]. But wavelets provide the various advantages over other transform methods. Wavelets offer high compression ratio. Wavelets results in better reconstructed image even at high compression ratio. The better image quality at high compression ratio is the main goal of image compression.

II. PRINCIPLES OF IMAGE COMPRESSION

Image Compression reduces the amount of data i.e number of bits required to represent a digital image. A digital image is representation of 2D image[2]. Digital images have finite set of values called picture element or pixels . Pixels are smallest individual element in image having values that represent brightness of color. Digital images are created by input devices such as digital cameras , scanners etc.The basis of reduction process is removal of redundant data. So to compress the imges redundancy i.e duplication must be removed. There are 3 types of redundancy usually exist in images[6]. These are

A. Coding redundancy
B. Interpixel redundancy
C. Psychovisual redundancy

Coding redundancy is removed by assigning the fewer bits to symbols occurring frequently and more number of bits to symols that occurs rarely. This makes code word length decreases. Interpixel Redunancy is the correlation between pixel values.This redundancy is removed by predicting the pixel value based on value of its neighour, Psychovisual Redundancy is human eye does not respond with equal sensitivity to all information.This redundancy is removed by deleting that information then this type of information has no effect on quality of image as eye can't see it. Compressing an image is different than compressing binary data[3]. Basiically there are 2 compression schemes which reduces the size of graphical file are Lossless and Lossy schemes. Lossless are used when image quality is more important than file size. Lossless are reversible so that exact original data can be reconstructed. This is the case when binary data such as documents , programs are compressed. They need to be exactly reproduced when decompressed . A single error in program can damage the meaning of whole life.Lossy compression takes advantage of information that is ignored by human visual system and discards invisible information. Lossy compression is one where compressing data and then decompressing it retrieves data that may well be different from the original.Lossy accept some loss of data in order to achieve high compression ratio. High compression ratio is needed when image is transferred over the network. Images need not to be reproduced exactly . An approximation of original image is enough for most purposes, as long as error between original and compressed image are tolerable.Thus lossy compression offers a tradeoff between number of bits required to represent a image and quality of image. Three measures are used to compare the performance of image compression techniques . Retain energy is amount of information retained by an image after compression is retaned energy. Higher the value of retained energy higher the energy preserved means less loss of information is there. If retained energy is 100% then compression is lossless and image can be reconstructed exactly. If there are changes in retained energy values then compression is lossy. Lossy compression is mainly used to compress multimedia data. Compression ratio is the number of zeroes present in the compressed image vector divided by total length of the compressed image vector. Greater the no of zeros greater the compression ratio that can be achieved. Peak signal to noise ratio(PSNR) is mainly used to measure

the quality of image. PSNR is measure of peak error Between original and compressed image. PSNR can be calculated with the following formula:-

PSNR= $20*\log_{10}(255/\text{sqrt}(MSE))$ [8]

Where 'MSE' is Mean Square Error

Lower value of MSE means lesser error.Logically, a higher value of 'PSNR' is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. So an image is considered as better one with high PSNR and lesser MSE.

III. WAVELETS

A. Wavelet Evolution

Wavelet Compression is a form of data compression and basically used for image compression. The goal of wavelet compression is to store the image in less space as possible in a file.With wavelets an image can be compressed to greater extent as compared to any other method. Wavelets are useful in Signal processing and Image Compression. The principles of Wavelets are similar to those of Fourier Transform(FT) which was first developed in 19th century. Fourier transforms breakdown a signal into sinosuiods of different frequencies. So Fourier transform are useful for providing the frequency information.that can not be seen in time domain[2] . The original signal i.e unprocessed signal depends upon the time so called time domain representation of signal and fourier transform depends upon time so called frequency domain representation of signal. FT only give frequency information time information is lost i.e it does tell the time when these frequencies occur[15].So a function is needed which gives both time and frequency information.

Then Dennis Gabor invented the Short Time Fourier Analysis (STFT). It provides both time and frequency information but with limited precisin due to fixed size 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. This gives rise to wavelets . Wavelets provide both time and frequency information with variable size window so called time frequency representation of signal[2]. Wavelets give better signal representation using multiresolution analysis. Multiresolution analysis means analyzes the signal at different frequencies with different resolutions. Multiresolution analysis gives good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies[4]. The power and magic of wavelet analysis is exactly this multiresolution analysis. Consider a sinosuiod and a wavelet . Wavelets are discrete , they have finite length and can't extend from $-\infty$ to ∞.as opposed to sine or cosine wave which are continous and infinite in length from $-\infty$ to ∞ [15].

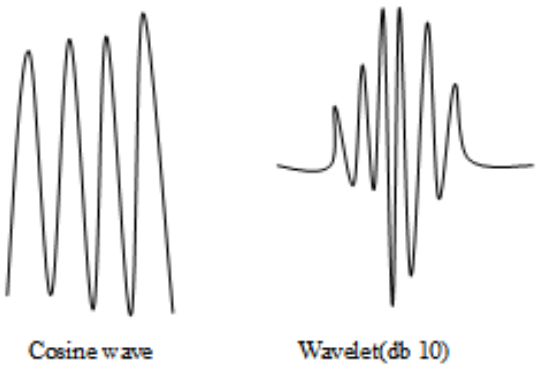

Figure-1 Sinosuiod and Wavelet

Signal with sharp changes can be better analysed with wavelets than with smooth sinosuiod. Wavelet analysis also reveals the aspects of data that other techniques can't reveal like trends , breakdown points , discontinuities and self similarlarties[15]. A large number of in-built wavelet filters have been provided by the developers of the tool wavelet toolbox for MATLAB environment including Haar, Daubetchies, Orthogonal, Symlets, Coiflets and Biorthogonal. Biorthogonal is the first choice of researchers because of the large range of linear phase filters present in this wavelet filters family.It has filters for both decomposition and reconstruction means exact reconstruction is possible in wavelet fiter family as compared to others filters.

B. Wavelet Transform

Image Processing involes filtering an image using the various filters. Wavelet transform is implemented using Discrete Wavelet Transform i.e image is decomposed using DWT. It uses two filters low pass and high pass filter. High pass filter only allow high frequency components to pass and block low frequency components. Low pass filter only pass low frequency components and block high frequency components. Low frequency components gives signal its identity and is considered as base of image and high frequency components imparts flavor and add to refine images. Wavelets divide the image in 2 parts approximation and detail coefficients. Approximations(main information) are low frequency components of signal and detail(fine information) are high frequency component of signal. A signal is passed through two filters low pass and high pass filter and is downsampled by 2 . This produces the detail coefficients(from high pass filter) and approximation coefficients (from low pass filter). This give single level of Decomposition. To obtain multiple decomposition approximation coefficients are again decomposed with low pass and high pass filter and is downsampled by 2.This decomposition process proceed only until the individual detail consist of single sample or pixel[15]. In Fig 2 'S' denotes the original signal, 'A' denotes the Approximation of the signal and 'D' denotes the detail of the signal. For, reconstructing the signal 'S', approximations 'A' and details 'D' are passed through the low pass and high pass filters in the reverse manner as shown in Fig 3.

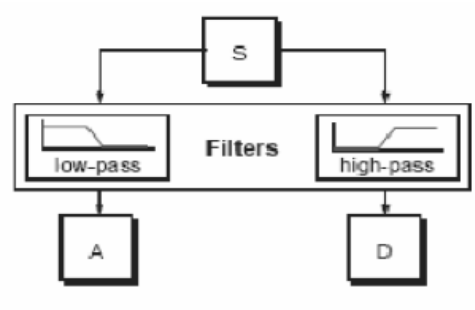

Figure-2 Filtering Process

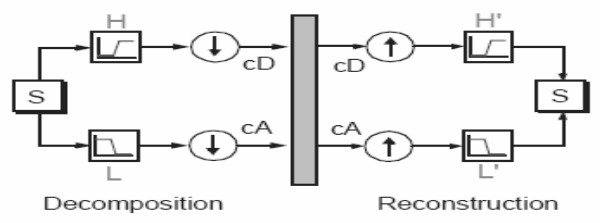

Figure-3 Image Decmposition and Reconstruction

The 1 D transform can be extended to 2D using different filters. Low pass filter are applied to each row of data this produces low frequency outputs. Then high pass filter is applied for same row of data this produces high frequency components. Then these filters are applied along each coloumn. This produces four subbands LL (approximation),HL (horizontal detail) , LH(vertical detail), HH(diagonal detail). So 2D DWT is performed by applying 1-D transform along rows and then along coloums[6]

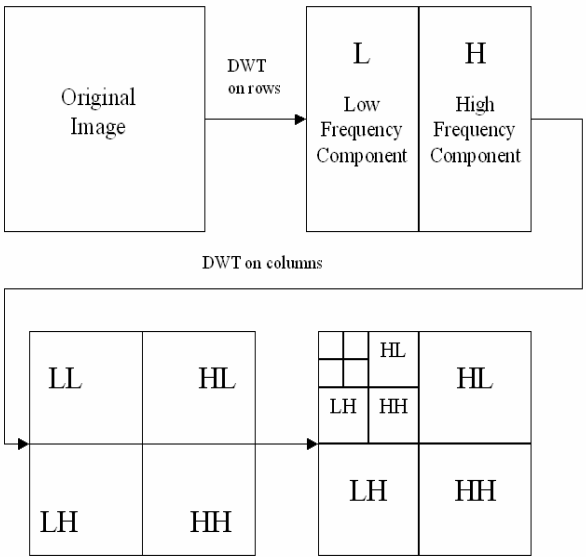

Figure-4 Image decomposition at 3 levels

IV. APPLICATIONS OF WAVELETS

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

A. Image Processing
B. Signal Processing
C. Progressive image compression (useful for low bit rate)
D. Fingerprint Verification
E. ECG (electrical activity of the heart, electrocardiograph)
F. Speech Recognization
G. EEG (electrical activity of the brain, electroence phalograph)
H. De-noising a signal
I. EMG (electrical activity of the muscles, electromyogram).

V. ADVANTAGES OF WAVELETS

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

A. Wavelet schemes at higher compression avoid blocking artifacts.
B. Wavelets provides both time and frequency information hence giving time frequency representation of signal with variable size window.
C. Wavelets are better matched to the HVS (Human Visual System**)** characteristics.
D. Wavelets are capable of revealing aspects like drifts, breakdown points, discontinuity, self similarity.
E. Wavelets compress a image or denoise a signal without appreciable degradation.
F. Wavelets results in better reconstructed image even at high compression ratio.
   Wavelets use fast wavelet transform i.e DWT(from where signal passes and coefficients emerge) therefore it's computation is fast.
G. Wavelets also provide an efficient decomposition of signals prior to compression.
H. Wavelet compression is very efficient at low bit rates.
I. Wavelets allow multiresolution analysis Some parts of signal to be resolved well in time and some parts of signal to be resolved well in frequency.
   Wavelets are irregular . So signals with sharp changes are better analyzed with irregular wavelet.

VI. CONCLUSION

In this paper , we have discussed all about wavelets – a better technique for image compression. Fourier Transform has some drawbacks these drawbacks give rise to wavelets. We have also discussed about Fourier Transform and Wavelets in brief. There are various applications and advantages of wavelets. So wavelets are better and reliable technique in field of image processing than any other existing methods.

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