Performance Analysis of Image Compression Using DWT And WPT

V.Priya[1], Dr.B.Ananthi[2]

[1]assistant Professor, Department Of Computer Science, Vellalar College For Women, Tamil Nadu, India Email: Priyakarthi8@Gmail.Com

[2]assistant Professor& Head, Department Of Computer Science, Vellalar College For Women, Tamil Nadu, India Email: Ananthibalamohan@Gmail.Com

Abstract: *With the increasing growth of technology and the entrance into the digital age, one has to handle a vast amount of information every time which often presents difficulties. So, the digital information must be stored and retrieved in an efficient and effective manner, in order for it to be put to practical use. Wavelets provide a mathematical way of encoding information in such a way that it is layered according to level of detail. This layering facilitates approximations at various intermediate stages. These approximations can be stored using a lot less space than the original data. This paper aims at the analysis on image compression technique using Discrete Wavelet Transform (DWT) and Wavelet Packet Transform (WPT) with Set Partitioning in Hierarchical Tree (SPIHT). Finally a performance comparison is made between the techniques based on different parameters like Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR), Mean Square Error (MSE) and Root Mean Square Error (RMSE).*

Keywords: DWT, WPT, SPIHT.

1. Introduction

The use of digital images is increasing rapidly. Along with this increasing use of digital images comes the serious issue of storing and transferring the huge volume of data representing the images because the uncompressed multimedia data requires considerable storage capacity and transmission bandwidth. Image compression is to reduce the redundancy of the image and to store or transmit data in an efficient form. The main purpose of image compression is to reduce the redundancy and irrelevancy present in the image, so that it can be stored and transferred efficiently. The compressed image is represented by less number of bits compared to original. Hence, the required storage size will be reduced, consequently maximum images can be stored and it can transferred in faster way to save the time, transmission bandwidth.

2. WAVELET ANALYSIS

A wavelet is a kind of mathematical function used to divide a given function or continuous-time signal into different frequency components and study each component with a resolution that matches its scale. A wavelet transform is the representation of a function by wavelets. The wavelets are scaled and translated copies (known as "daughter wavelets") of a finite-length or fast-decaying oscillating waveform (known as the "mother wavelet").

Wavelet transform exploits both the spatial and frequency correlation of data by dilations (or contractions) and translations of mother wavelet on the input data. It supports the multiresolution analysis of data (i.e.) it can be applied to different scales according to the details required, which allows progressive transmission and zooming of the image without the need of extra storage. Another encouraging feature of wavelet transform is its symmetric nature that is both the forward and the inverse transform has the same complexity, building fast compression and decompression routines. Its characteristics well suited for image compression include the ability to take into account of Human Visual System's (HVS) characteristics, very good energy compaction capabilities, robustness under transmission, high compression ratio etc.

3. Discrete Wavelet Transform (DWT)

In DWT, a time-scale representation of the digital signal is obtained using digital filtering techniques. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales. The two dimensional discrete wavelet transform is essentially a one dimensional analysis of a two dimensional signal. It only operates on one dimension at a time, by analyzing the rows and columns of an image in a separable fashion. The first step applies the Haar wavelet filter to decompose the image into regions such that one region contains large numbers and the other region contains small numbers. This produces two new images. Rows and columns analyzed with a high pass filter are designated as H. Likewise, rows and columns analyzed with a low pass filter are designated as L. Next, analysed filters are applied

to the columns of each new image, to produce four different images called subbands. If a subband image was produced using a high pass filter on the rows and a low pass filter on the columns, it is called the HL subband. Each subband provides different information about the image. The LL subband is a coarse approximation of the image and removes all high frequency information. The LH subband removes high frequency information along the rows and emphasizes high frequency information along the columns. The result is an image in which vertical edges are emphasized. The HL subband emphasizes horizontal edges, and the HH subband emphasizes diagonal edges [3], [4].

To compute the DWT of the image at the next scale, the process is applied again to the LL subband. The high and low pass filters operate separately on the rows and columns to create four different subbands such as LL1, LH1, HL1 and HH1 which is shown in the figure 1.
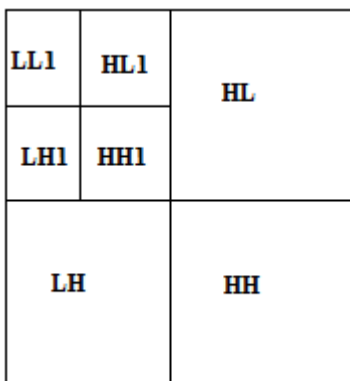

Figure1: 2-LEVEL DWT SCHEME

4. Wavelet Packet Transform (WPT)

Wavelet packet transform (WPT) is a generalization of the Discrete Wavelet Transform (DWT) that offers a rich set of decomposition structures. Wavelet packets are the conventional wavelet transforms in which the details are iteratively filtered. A multilevel wavelet filter bank involves iterating the low pass and high pass filtering and down sampling procedure on the output of low pass branch and high pass branch of previous stage to form a full tree decomposition. The wavelet packet transform applies the transform step to both the low pass and the high pass result.
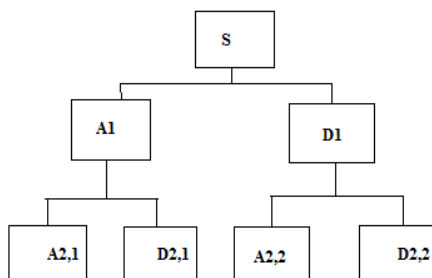

Figure 2: Wavelet Packet Transform

As shown in figure 2, the wavelet packet transform can be viewed as a tree. The root of the tree is the original data set. The next level of the tree is the result of one step of the wavelet transform. Subsequent levels in the tree are constructed by recursively applying the wavelet transform

step to the low and high pass filter results of the previous wavelet transform step. The wavelet function used to construct the wavelet packet tree is a version of the Haar wavelet function.

The WPT can be viewed as a tree. The wavelet function used to construct the wavelet packet tree is the version of the Haar wavelet function. The Haar wavelet function used for the WPT is

Hara Scaling (low pass) function:

$$S_{j+1,i} = \frac{even_{j,i} + odd_{j,i}}{2} \qquad (1)$$

Hara wavelet (high pass) function:

$$d_{j+1,i} = \frac{even_{j,i} - odd_{j,i}}{2} \qquad (2)$$

The wavelet basis is the range in the vector over which the scaling and wavelet functions are non-zero. For the Haar wavelet the basis is an increasing power of two, relative to the original data set. The first level following the data has a basis of two (the average and average difference is calculated on two elements). The next level has a basis of four, since the two elements used to calculate the scaling and wavelet functions are result of four elements in the original data. The next level has a basis of eight, and so on [1],[7]. The figure 3 shows the first level of the WPT decomposition.
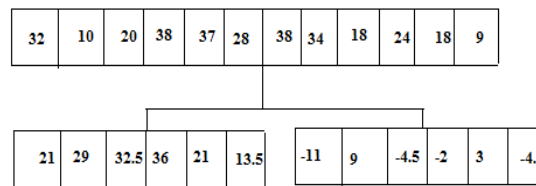

Figure 3: Wavelet Packet Tree

5. QUANTIZATION

Quantization refers to the process of approximating the continuous set of values in the image data with a finite set of values. The input to a quantizer is the original data, and the output is always one among a finite number of levels. The quantizer is a function whose set of output values is discrete, and usually finite. Obviously, this is a process of approximation, and a good quantizer is one, which represents the original signal with minimum loss or distortion.

There are two types of quantization: Vector Quantization (VQ) and Scalar Quantization (SQ). In Scalar Quantization (SQ), each input symbol is treated separately in producing the output. If the input range is divided into levels of equal spacing, then the quantizer is termed as a uniform quantizer, and if not, it is termed as a non-uniform quantizer. A uniform quantizer can be easily specified by its lower bound and the step size. Also, implementing the uniform quantizer is easier than a non-uniform quantizer. In this prposed work SQ has been applied for both DWT and WPT coefficient values.

6. Set Partitioning in Hierarchical Trees (SPIHT)

SPIHT coding is important to have the encoder and decoder test sets for significances, so the coding algorithm

uses three lists called List of Significant Pixels (LSP), List of Insignificant Pixels (LIP), and List of Insignificant Sets (LIS). These are coefficient location lists that contain their coordinates. After the initialization, the algorithm takes two stages for each level of threshold- the sorting pass (in which lists are organized) and the refinement pass (which does the actual progressive coding transmission). The result is in the form of bit stream. The LIP contains coordinates of coefficients that were insignificant in the previous sorting pass. In the current pass they were tested, and those that test significant are moved to the LSP. In a similar way, sets in the LIS are tested in sequential order, and when a set is found to be significant, it is removed from LIS and is partitioned. The new subsets with more than one coefficient are placed back in the LIS, to be tested latter, and the subsets with one element are tested and appended to the LIP or the LSP, depending on the result of the test, the refinement pass transmits the nth most significant bit of the entries in the LSP [4],[7].

7. Proposed Methodology

The steps needed to compress an image are as follows:

- Digitize the source image into a signal, which is a string of numbers

- Decompose the signal into a sequence of wavelet coefficients

- Use quantization to convert coefficients to a sequence of binary symbols

- Apply entropy coding to compress it into binary strings

The first step in the compression process is to digitize the image using the wavelet. The digitized image can be characterized by its intensity levels, or scales of colour that range from 0to 255(RGB), and its resolution. The next step is wavelets process which processes the signal, but up to this point, compression has not yet occurred. The next step is quantization which converts a sequence of floating numbers to a sequence of integers. The simplest form is to round to the nearest integer. The last step encoding, is responsible for the actual compression. One method to compress the data is SPIHT encoding. With this method, an integer sequence is changed into a shorter sequence, with the numbers of bit streams.
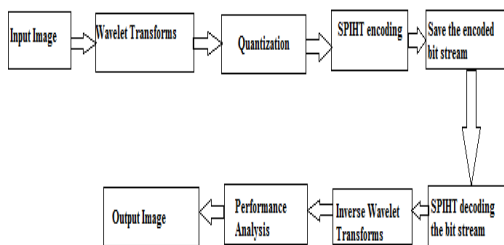
Figure3: ARCHITECTURE OF PROPOSED SYSTEM

To test the effectiveness of this proposed system, the image quality should be evaluated objectively. Standard objective measures of image quality are Mean Square Error (MSE) and Peak Signal Noise Ratio (PSNR) [6] which is defined as

$$PSNR = 10\log_{10}\left(\frac{255^2}{MxN}\right) \qquad (3)$$

Where MSE is

$$MSE = sum\frac{\left(sum(a-b)^2\right)}{MxN} \qquad (4)$$

where a = Input image size
b = Output image size
M = Number of rows
N = Number of columns
It is the average of square of the errors of the two images.

The Root Mean Square Error (RMSE) is defined as the square root of the MSE. That is

$$RMSE = \sqrt{MSE} \qquad (5)$$

MSE and PSNR are the most common methods for measuring the quality of compressed images. Compression Ratio is one of several measures that are commonly used to express the efficiency of a compression method. It is calculated as

$$CompressionRatio = \frac{sizeofoutputstream}{sizeofinputstream} \qquad (6)$$

Table 1: COMPRESSION RATIO, MSE, RMSE AND PSNR VALUES OF DWT

S.No	Image Name	Compression Ratio	MSE	RMSE	PSNR
1	Baby	0.517	1.474	1.214	40.298
2	Dolphin	0.558	22.311	4.723	34.398
3	Beach	0.541	3.862	1.965	38.206

Table 2: COMPRESSION RATIO, MSE, RMSE AND PSNR VALUES OF WPT

S.No	Image Name	Compression Ratio	MSE	RMSE	PSNR
1	Baby	0.743	3.228	1.796	43.048
2	Dolphin	0.618	4.068	2.146	41.549
3	Beach	0.429	4.666	2.160	41.442

8. CONCLUSION

The DWT is decomposed into two levels and WPT is also decomposed into one level respectively by using Haar wavelet. In this proposed work PSNR has been used as a qualitative measure based on the MSE and RMSE of the reconstructed image. Thus the analysis between PSNR values of WPT and DWT for the same images gives the measure of image quality. It has been shown that the PSNR values based on DWT range from 34 to 40 and WPT range from 41 to 48 respectively. The performance of DWT and WPT is analysed by using lossless image compression technique, SPIHT and the results demonstrate significant gain in WPT with good PSNR than DWT using SPIHT.

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Authors Profile

V.Priya received her M.Phill degree in Computer Science from Bharathiar University, India in 2009. At present she is pursuing her Ph.D.degree in Computer Science from Bharathiar University, India. Her research area is Image Processing. **Email**: priyakarthi8@gmail.com

Dr.B.Ananthi,MCA,M.Phil,Ph.D., Assistant Professor & Head, Department of Computer Science, Vellalar College for Women, Erode. She received her M.Phill degree in 2003 and Ph.D. Computer Science in 2011 from Mother Therasa University, India. Her area of interest is Image Processing. Her experience in the academics for more than 17 years. Adding up to her research interest, she has presented and published around 15 Research articles in the National and International Journals. **Email**: ananthibalamohan@gmail.com