Objective Performance of Picture Quality Measures based on Set Partitioning in Hierarchical Trees (SPIHT)

Dr.P. Sumitra
Assistant Professor, Department of Computer Science, Vivekanandha College of Arts and Sciences for Women (Autonomous)
Elayampalayam, Tiruchengode, Tamil Nadu, India
E-mail: sumitravaradharajan@gmail.com

Abstract - Image compression is an important tool to reduce the bandwidth and storage requirements of practical image systems. It has been successfully implemented to provide high compression rates while maintaining good image quality. Wavelet transform is the latest method of compression where in ability to describe any type of signal both in time and frequency domain. To explore the effect of various image features on the coding performance, a set of gray level image statistics have been analyzed by using SPIHT (Set Partitioning in Hierarchical Trees) algorithm. Applying the Discrete Wavelet Transform (DWT) coefficients and using SPIHT, image quality measures are determined for a standard Lena image, Boat and Cameraman image. SPIHT has been proposed as a method for effective and efficient embedded image coding. This method holds important features like MSE, PSNR, NCC, NAE. SPIHT has been successfully used in many application.

Index Terms— SPIHT, DWT, Image Quality Measure

1. Introduction

The image compression can be divided into two main categories namely lossless and lossy compression. With lossless compression, every single bit of data that was originally in the image remains after the image uncompressed and the information completely restored. On the other hand, lossy compression reduces an image by permanently eliminating certain information, especially redundant information. When the image is uncompressed only a part of the original information is retained there.

The DWT is a linear transformation that operates on a data vector whose length is an integer power of two, transforming it into a numerically different vector of the same length. There are several algorithms for wavelet based compression such as Embedded Zerotree Wavelet (EZW), Set Partitioning in Hierarchical Trees (SPIHT), Wavelet Difference Reduction (WDR), Adaptively Scanned Wavelet [1].

In 1996, Pearlman and Said developed a faster and more efficient image coding technology called Set Partitioning in Hiearchical trees [2][3][4]. It provides a better performance when compared to the Embedded Zero tree wavelet transform. SPIHT is an improved version of EZW. It improves the coding performance by exploiting the self-similarity of the coefficients across sub-bands more efficiently than EZW.

This paper implements SPHIT coding the MATLAB platform. It performs the entire picture quality that is measured objectively using Structural Content (SC), Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Normalized Cross-Correlation (NCC), Average Difference (AD), Maximum Difference (MD) and Normalized Absolute Error (NAE).

2. Discrete Wavelet Transform

Wavelet based image compression techniques are increasingly used for image compression. The wavelet based coding divides the image into different sub-bands. These sub-bands can then be successively quantized using different quantizers to give better compression.

DWT transforms discrete signal from the time domain into time frequency domain. It is a linear transformation that operates on a data vector whose length is an integer power of two, transforming it into a numerically different vector of the same length. It is a tool that separates data into different frequency components, and then studies each component with resolution matched to its scale. DWT is computed with a cascade of filtering followed by a factor 2 subsampling Fig. 1.

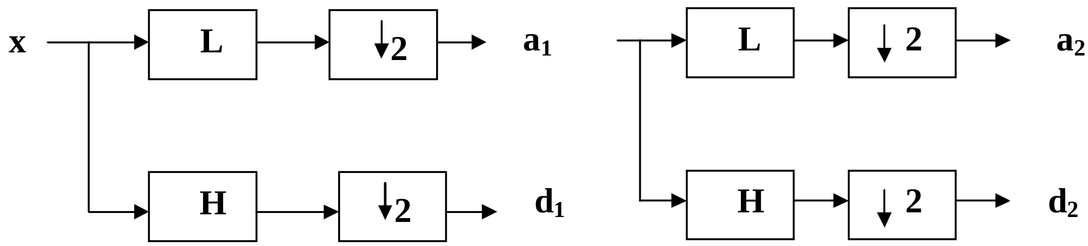

Fig. 1 DWT tree

H and L denote high and low-pass filters respectively. $\downarrow 2$ denote subsampling. Outputs of this filters are given by equation (1) and (2)

$$a_{j+1}[p] = \sum_{n=-\infty}^{+\infty} l[n-2p]\, a_j[n] \quad (1)$$

$$d_{j+1}[p] = \sum_{n=-\infty}^{+\infty} h[n-2p]\, a_j[n] \quad (2)$$

Elements a_j are used for next step(scale) of the transform and elements d_j, called wavelet coefficients determine output of the transform. l[n] and h[n] are coefficients of low and high-pass filters respectively. DWT algorithm for two-dimensional pictures is similar. The DWT is performed firstly for all image rows and then for all columns is shown in Fig. 2.

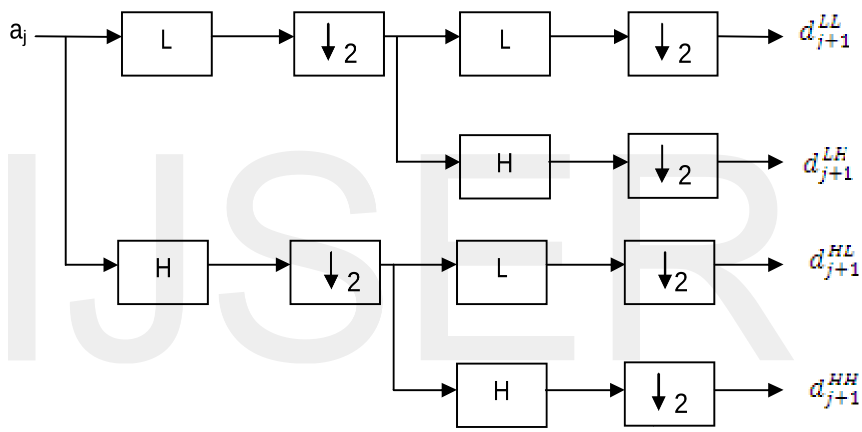

Fig. 2 Wavelet Decomposition for two dimensional pictures

The main feature of DWT is multiscale representation of function. By using the wavelets, given function can be analyzed at various levels of resolution. For the sample, Fig.3 shows the sub-bands of image Lena.

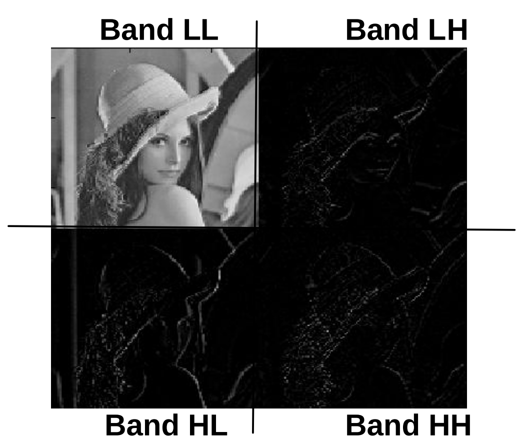

Fig. 3 One level of 2D-DWT

International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July 2014
ISSN 2229-5518

3. SPIHT Algorithm

One of the most efficient algorithms in the area of image compression is the Set Partitioning in Hierarchical Trees (SPIHT). The coefficients of wavelet transformed image are classified in three sets:

1. The list of insignificant pixels (LIP) which contains the coordinates of those coefficients which are insignificant with respect to the current threshold th.
2. The list of significant pixels (LSP) which contains the coordinates of those coefficients which are significant with respect to threshold, and
3. The list of insignificant sets (LIS) which contains the coordinates of the roots of insignificant subtrees.

At the beginning, LSP is empty, LIP keeps all coefficients in the lowest subband, and LIS keeps all tree roots which are at the lowest subband. SPIHT starts coding by running two passes [5].

3.1 Sorting Pass

It first browses the LIP and moves all significant coefficients to LSP and output its sign. Then it browses LIS executing the significance information and following the partitioning sorting algorithms.

3.2 Refining pass

It browses the coefficients in LSP and outputs a single bit alone based on the current threshold. After the two passes are finished, the threshold is divided by 2 and the encoder executes the two passes again. This procedure is recursively applied until the number of output bits reaches the desired number.

4. Picture Quality Measures

The objective numerical measures of picture quality [6] that are based on computable distortion measures like mean square error, peak signal to noise ratio, average distance, maximum difference, normalized error, structural correlation are considered for study in this work on the original image $f(i,j)$ and on the decompressed image $f'(i,j)$.

4.1 Mean Square Error

Mean Square Error (MSE) measures the average of the cumulative square error between the original and the reconstructed image. The MSE is computed as

$$MSE = \left(\frac{1}{NxM}\right) \sum_{i=1}^{N} \sum_{j=1}^{M} \left(f(i,j) - f'(i,j)\right)^2 \qquad (3)$$

Where NxM is the size of image, $f'(i,j)$ are the values of the pixel element of the reconstructed and original pixel element at $f(i,j)$ of the image respectively.

4.2 Root Mean Square Error

The Root Mean Square Error (RMSE) is the square root of mean square error. It quantifies the average sum of distortion in each pixel of the reconstructed image.

$$RMSE = \sqrt{MSE} \qquad (4)$$

4.3 Peak Signal to Noise Ratio

The Peak Signal to Noise Ratio (PSNR) measures the quality of reconstructed image compared with the original image and a standard way to measure image fidelity.

$$PSNR = 20 \log_{10}\left[\frac{N}{R_m}\right] \text{ dB} \qquad (5)$$

4.4 Average Difference

A lower value of Average Difference (AD) gives a “cleaner” image as more noise is reduced and it is computed using Eg. (6).

$$AD = \left(\frac{1}{MN}\right) \sum_{i=1}^{M} \sum_{j=1}^{N} \left(f(i,j) - f'(i,j)\right) \qquad (6)$$

4.5 Maximum Difference

Maximum Difference (MD) is calculated using Eq. (7) is preferred as a very simple measure as a reference for measuring compressed picture quality in different compressions [7].

$$MD = Max\left(\left|f(i,j) - f'(i,j)\right|\right) \qquad (7)$$

4.6 Normalised Cross-Correlation

The closeness between two digital images can also be quantified in terms of correlation function. All the correlation based measures tend to 1, as the difference between two images tend to zero. As difference measure and correlation measures complement each other, minimizing distance measures are maximizing correlation measure and normalised correlation is given by Eq. (8)

$$NCC = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \left(f(i,j).f'(i,j)\right)}{\sum_{i=1}^{M} \sum_{j=1}^{N} f(i,j)^2} \qquad (8)$$

4.7 Normalised Absolute Error

$$NAE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|f(i,j), f'(i,j)|}{\sum_{i=1}^{M}\sum_{j=1}^{N}|f(i,j)|} \quad (9)$$

NAE is a measure of how far is the decompressed image from the original image with the value of zero being the perfect fit. Large value of NAE indicates poor quality of the image [9].

4.8 Structural Correlation

Correlation estimates the similarity of the structure of two signals. This measure effectively compares the total weight of an original signal to that of a coded is

$$SC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} f(i,j)^2}{\sum_{i=1}^{M}\sum_{j=1}^{N} f'(i,j)^2} \quad (10)$$

5. Results and Discussions

Table 1, Table 2 and Table 3 obtained the picture quality measures for the image cameraman, boat and lena respectively.

Table 1 Picture Quality measures of image cameraman for the size 256 x 256

bpp	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
MSE	279.49	157.66	108.53	78.17	58.00	46.08	36.82	28.52	21.96
PSNR	23.67dB	26.15dB	27.78dB	29.20dB	30.50dB	31.50dB	32.47dB	33.58dB	34.72dB
NCC	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
AD	-0.03	0.10	0.10	0.10	0.04	0.04	0.04	0.04	0.01
MD	125.84	99.00	92.53	66.93	48.83	49.16	49.16	38.01	26.72
NAE	0.09	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03
SC	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2 Picture Quality measures of image boat for the size 256 x 256

bpp	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
MSE	319.27	211.42	153.04	120.80	94.52	73.76	60.97	50.98	42.16
PSNR	23.09dB	24.88dB	26.28dB	27.31dB	28.38dB	29.45dB	30.28dB	31.06dB	31.88dB
NCC	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
AD	-0.22	-0.22	-0.09	-0.09	-0.09	-0.03	-0.03	-0.03	-0.03
MD	150.23	106.16	97.76	86.21	66.90	46.02	45.14	40.35	40.27
NAE	0.09	0.07	0.06	0.06	0.05	0.04	0.04	0.04	0.03
SC	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3 Picture Quality measures of image lena for the size 256 x 256

bpp	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
MSE	238.17	128.92	88.35	60.62	44.70	35.74	27.84	21.58	17.26
PSNR	24.36dB	27.03dB	28.67dB	30.30dB	31.63dB	32.60dB	33.68dB	34.79dB	35.68dB
NCC	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
AD	-0.07	0.06	0.06	-0.01	-0.01	-0.01	-0.01	0.02	0.02
MD	117.00	78.91	72.38	57.03	45.61	42.83	41.12	29.79	24.08
NAE	0.11	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.03
SC	1.01	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00

Average difference with low value indicates a good quality image and that is observed with the value of 0.22 for boat image for bpp= 0.1 & 0.2 respectively. For cameraman it is the maximum with 0.10 for bpp = 0.2, 0.3 and 0.4 respectively.

Normalised correlation gives closeness between the original and decode image and is obtained for cameraman, boat and lena image as 1.00 for bpp = 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 respectively. NAE which is a measure to study the quality of approximation of the images having maximum 0.09, 0.11 for cameraman, boat and lena image respectively.

The structural content is a global measure which compares the total weight of the compressed image and original image, is 1.00 for cameraman, 1.00 for boat image and 1.00 for lena image. The structural content with value spread at 1, indicates a better quality image.

Of all the objective quality measures, PSNR which is the most commonly used quality measure which reflects the quality of decoded images approximately. For all the image used in this analysis, for the images compressed using SPIHT, the PSNR of the image lies between 20dB and 40 dB[9] which indicates that the images are of good acceptable quality.

Reference

[1] Kamrul Hasan Talukder and Koichi Harada, "Enhancement of Discrete Wavelet Transform (DWT) for Image Transmission over Internet", 2011 Eighth International Conference on Information Technology: New Generations.

[2] Said. A and Pearlman W.A. "A New, Fast and Efficient image codec based on Set Partitioning in Hiearchical Trees", IEEE Transactions on Circuits and Systems for Video Technology, Vol. 6, No. 3, pp.243-25, June 1996.

[3] Shapiro. J,"Embedded Image Coding Using Zero-Trees of Wavelet Coefficients", IEEE Transactions on Signal Processing, Vol. 41, No.12,pp. 3445-3462,1993.

[4] Said, W.A. Pearlman," Image Compression using the spatial-orientation tree", IEEE International Symposium on Circuits and Systems, Chicago, Il, pp. 279-282,1993.

[5] Wei Li, Zhen Peng pang," SPIHT Algorithm with Huffman Encoding", Intelligent Information technology and Security Informatics (IITSI), Third International Symposium, 22 April 2010.

[6] Tomas Kratochvil and Pavel Simicek (2005)," Utilization of MATLAB for picture quality evaluation", Institute of Radio Electronics, Brno University of Technology Czech, Republic.

[7] Marta Mrak, Sonja Grgic and Mislav Grgic (2003), " Picture Quality Measures in Image Compression Systems", Eurocon 2003, Vol. 1, pp. 233-236.

[8]Ratchakit Sakullee and Somkait Udomhunsakul(2007)," Objective Performance of Compressed Image Quality Assessments", PWASET, Vol. 26, pp.434-443.

[9] Netravali A.N and Haskell B.G, "Digital Pictures: Representation, compression and standards", 2nd edition, Plenum Press, U.S.A, 1995.