A New, Fast and Efficient Wavelet Based Image Compression Technique Using JPEG2000 with EBCOT versus SPIHT

P. Sumitra

Abstract: *A wavelet is a function like a small wave and a ripple of baseline. The Wavelet Transform (WT) is a technique for analyzing signals. It was developed as an alternative to the Short Time Fourier Transform (STFT) to overcome the problems related to its frequency and time resolution properties. Wavelet can be used to represent data as diverse as heart beats and television signals, in a way that reduces redundancy within the signal. Therefore it can be used for image compression. This paper focuses important features of wavelet transform in compression of still images, including the extent to which the quality of image is degraded by the process of wavelet compression and decompression. The techniques used are Set* **Partitioning In Hierarchical Trees** *(SPIHT) and Embedded Block Coding Optimal Truncation Code (EBCOT). These techniques are more efficient and provide a better quality in the image. In compression, wavelets have shown a good adaptability to a wide range of data, while being of reasonable complexity. The above techniques have been successfully used in many applications. The techniques are compared by using the performance parameters PSNR. Images obtained with those techniques yield very good results.*

Keywords: *EBCOT, JPEG2000, SPIHT, DWT, VQ, SQ.*

I. INTRODUCTION

Image Compression is an important area in the field of digital image processing [1]. Digital image compression is used to reduce the number of bits required to store an image in a computer memory and/or transmit it over a communication link. For many contemporary applications, such as distributed multimedia systems, rapid transmission of images is necessary. Cost of transmission and storage tends to be directly proportional to the volume of data. Therefore, application of digital image compression techniques becomes necessary to minimize the cost. A number of digital image compression algorithms have been developed and standardized. Image compression research techniques are broadly classified into lossless compression and lossy compression. In lossless compression methods, there will be no loss of data after decompression, but the compression ratio is low. In lossy compression, there will be some loss of data in the decompressed image, but the compression ratio is high. Some of the methods of lossless compression are Run-length Encoding, DPCM, Predictive Coding and Entropy coding. Some of the methods of lossy compression are transform coding, wavelet compression, and fractal compression. Wavelet compression is a form of data compression well suited for image and audio compression [2][3]. The desirable properties of wavelet transforms are 1) orthogonality 2) compact support 3) linear phase and high approximation movements of the basis function 4) efficient multi-resolution representation 5) scalability, and 6) embedded coding with progressive transmission. Various methods for coding of image wavelet coefficients are known. Manik Groach et al [4] proposed an efficient hybrid image compression scheme combining Discrete Cosine Transform and Set Partitioning in Hierarchical Trees (SPIHT) coding for effectual compression of images. The proposed method gives better or close quality to the SPIHT. Bibhuprasad Mohanty et al [5] have presented a novel extension technique to the Set Partitioning in Hierarchical Trees based image compression with spatial scalability. The experimental results show that it performs better measurably and also at lower bit rate its performance is well suited for the purpose of surveillance and monitoring system. Rehna et al [6] presented an improved method of compression using SPIHT algorithm by reducing the computational and time complexity. The results show that the performance of the SPIHT based compression algorithm is hence improved without compromising on the PSNR. Rest of the paper is organized as follows: section II deals with the discrete wavelet transform. SPIHT algorithm is explained in section III. JPEG2000 architecture is described in section IV. Section V explains about the proposed method of JPEG2000 with EBCOT. Results obtained are shown in section VI and finally, the conclusion of the paper is presented in section VII.

II. DISCRETE WAVELET TRANSFORM

A wavelet is function like a small wave and a ripple of baseline. The Wavelet Transform (WT) is a technique for analyzing signals. It was developed as an alternative to the Short Time Fourier Transform (STFT) to overcome the problems related to its frequency and time resolution properties. Wavelet can be used to represent data as diverse as heart beats and television signals, in a way that reduces redundancy within the signal. Therefore it can be used for compression. The DWT is a branch of the wavelet transform that is adapted for multi-resolution image [7], digital signal processing applications [8] [9] and in many other image processing applications. JPEG2000 which is the standards of international image coding is adopted the method of wavelet transform coding. An M*N image is decomposed using wavelet transform.

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* Correspondence Author
Dr. P. Sumitra, Professor, Vasavi Vidya Trust Group of Institutions (Vysya College Campus), Affiliated to Anna University, Chennai, Masinaickempatti, Salem .

The image is decomposed into four transform coefficient sets LL, HL, LH and HH are created. LL corresponds to application of either a low pass filter or high pass filter to the rows and HL refers to the filter applied to the columns. The DWT applied on an image is depicted in Fig.1.

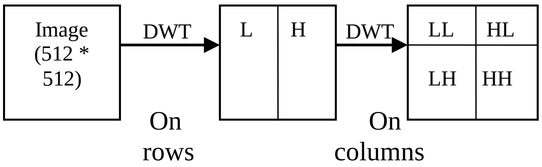

Fig 1: DWT is applied on an image

We can use multiple levels of wavelet transforms to concentrate data energy in the lowest sampled bands. The LL subband can then be transformed to LL2, HL2, LH2 and HH2 subbands, producing a two-level wavelet transform.

III. SPIHT

Set Partitioning In Hierarchical Trees (SPIHT) image coding algorithm was developed in 1996 by Said and Pearlman, is one of the powerful wavelet-based algorithm for the image compression [10][11]. The wavelet transform is applied to an image, the algorithm works by partitioning the wavelet decomposed image into significant and insignificant partitions based on the following function [12].

$$S_n(T) = \begin{cases} 1, & \max_{(i,j)\in T} \{ |c_{i,j}| \} \geq 2^n \\ 0, & \text{Otherwise} \end{cases} \quad (1)$$

where $S_n(T)$, is the significance of a set of co-ordinates T, and $c_{i,j}$ is the coefficient value at co-ordinate (i,j). SPIHT algorithm is based on the following concepts [13] [14].

i. Ordered bit plane progressive transmission.
ii. Set partitioning sorting algorithm
iii. Spatial orientation trees.

SPIHT keeps three lists: The sorting pass List of insignificant pixels (LIP), List of insignificant sets (LIS), and List of significant pixels (LSP). LIP stores insignificant pixels, LSP stores significant pixels and LIS stores insignificant sets. At the beginning, LSP is empty, LIP keeps all coefficients in the lowest sub band, and LIS keeps all tree roots which are at the lowest sub band. There are two passes in the algorithm – the sorting pass and the refinement pass. The sorting pass browses the LIP and moves all the significant coefficients to LSP and outputs its sign. Then it browses LIS executing the significance information and following the partitioning sorting algorithms. The refinement pass 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.

IV. JPEG2000 ARCHITECTURE

JPEG2000 is the latest image compression standard developed jointly by the ISO/ITU-T to complement the current emerge from the body popularly known as the Joint Photographic Experts Group (JPEG)[15][16]. JPEG2000 is a new wavelet based compression methodology that provides many benefits over DCT compression method which was used in the JPEG format. The wavelet compression converts the image into a series of wavelets that can be stored more efficiently than pixel blocks. The architecture of the JPEG2000 encoder and decoder are shown in Fig.2.

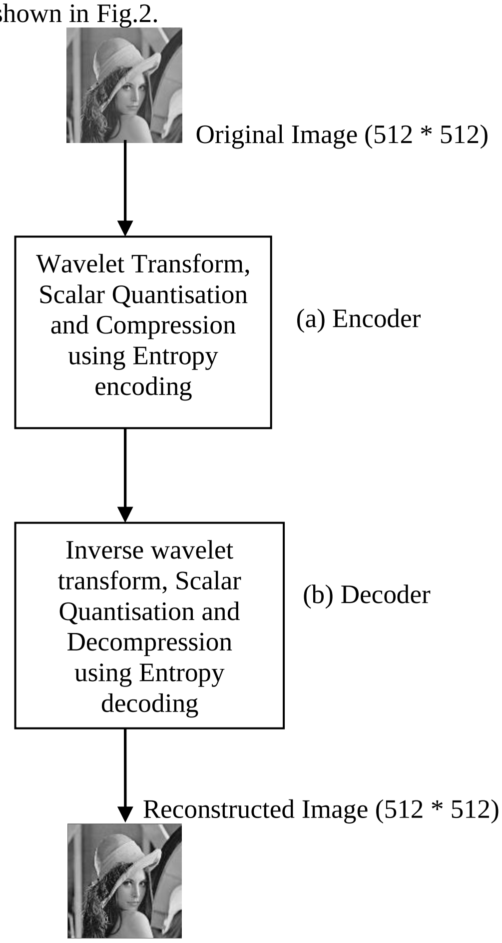

Fig. 2 Architecture of the JPEG2000 (a) Encoder (b) Decoder

In JPEG2000, a DWT is used to decompose each tile component into different sub-bands where subband is defined as any form of transform coding that breaks a signal into a number of different frequency bands and encodes each one independently. After transformation, all coefficients are quantized using scalar quantization. Quantization allows greater compression to be achieved, by representing transform coefficients with only the minimal precision required to obtain the desired level of image quality. Quantization of transform coefficients is one of the two primary sources of information loss in the coding path. The coefficients are entropy coded, and sent as output codestream (bit stream). The JPEG2000 standard works on image tiles. The source image is partitioned into rectangular non-overlapping blocks in a process called tiles. The tiles are then compressed independently. All operations including component mixing, wavelet transform, quantization and entropy coding are performed independently on each tile. Tiling is used to reduce the memory requirements. Each tile is reconstructed independently so that they can be used to decode specific parts of the image. Each tile is an array of integers represented in sign-magnitude form.

V. PROPOSED METHOD OF JPEG2000 WITH EBCOT

The aim of this method is to present an image data compression method developed by modifying JPEG2000 method.

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We are removing entropy coding in original JPEG2000 and replacing it by Embedded Block Coding with Optimal Truncation (EBCOT). The compression engine of JPEG2000 with EBCOT (JPG2KEC) encoding and decoding is shown in Fig. 3.

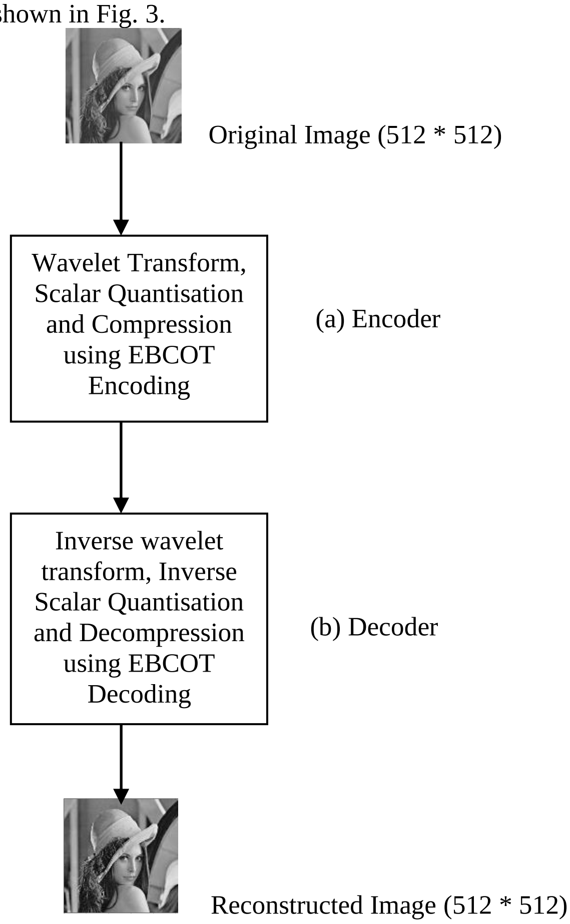

Fig: 3 Compression engine of JPEG2000 with EBCOT (a) Encoder b) Decoder

The DWT is first applied on the given source image. Application DWT results in several decomposition levels. These decomposition levels contain a number of subbands that describe the horizontal and vertical spatial frequency characteristics of the original tile component planes. The DWT co-efficients are further quantized using scalar quantisation. Quantisation is the process by which the transform coefficients are reduced in precision. Each subband of the wavelet decomposition is divided into rectangular blocks, called code-blocks, which are coded independently using arithmetic coding. This approach is called EBCOT. Such a partitioning reduces memory requirements in both hardware and software implementations and provides a certain degree of spatial random access to the bitstream. The block size is identical for all subbands, so that blocks in lower resolution subbands span a larger region in the original image. The EBCOT algorithm is employed to compress the quantized DWT co-efficients.

A. EBCOT Procedure

In EBCOT, there are two coding stages, the first is the block bit-plane coding; where the wavelet coefficients associated with each sub-band are partitioned into fixed-size small blocks. Fig. 4 shows how to partition the wavelet coefficients. Then, a set of embedded bit streams for all small blocks is generated using bit-plane coding. The second stage is responsible for efficiently identifying the contribution of each small block to each bit-stream layer.

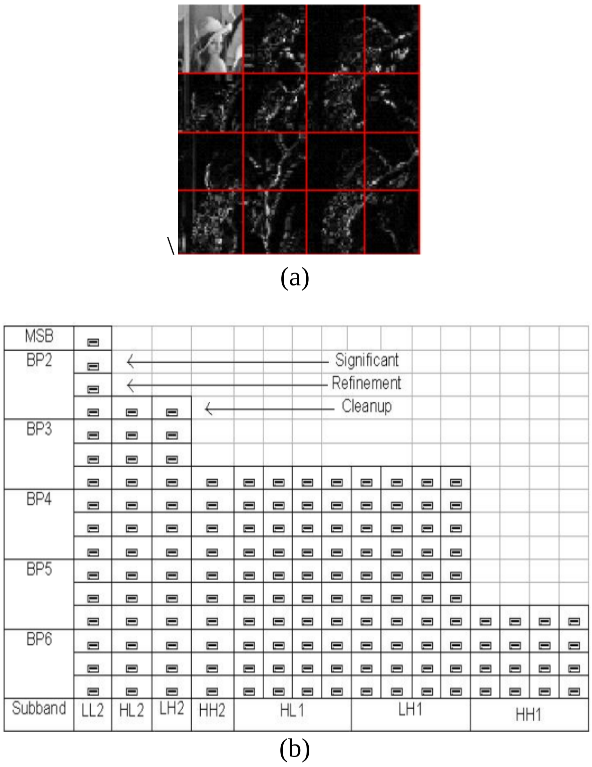

Fig: 4 (a) Block partition for the Lena image (b) Compressed data from every small block

The first coding stage is one of bit-plane coding. After all of the subbands have been partitioned into small blocks, each of the small blocks is independently encoded using a bit-plane coder. In this stage, there are three scan passes; the pass for significant bits is divided into two passes; a significance pass and a cleanup pass which are given below.

B. Significance propagation pass

The first coding pass for each bit plane is the significance pass. This pass is used to convey significance and sign information for samples that have not yet been found to be significant and are predicted to become significant during the processing of the current bit plane.

Significance pass algorithm

for each sample in code block **do**
if sample previously insignificant **and** predicted to become significant during current bit plane **then**
code significance of sample /* 1 binary symbol */
if sample significant **then**
code sign of sample /* 1 binary symbol */
endif
endif
endfor

C. Magnitude Refinement Pass

During this pass we skip over all samples except those which are already significant, and for which no information has been coded in the previous pass.

D. Refinement pass algorithm

for each sample in code block **do**
if sample found significant in previous bit plane **then**
code next most significant bit in sample /* 1 binary symbol */
endif
endfor

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E. Cleanup pass algorithm

If a sample is found to be significant in this process, its sign is coded immediately using the SC primitive.

Cleanup pass algorithm

for each vertical scan in code block **do**

if four samples in vertical scan **and** all previously insignificant and unvisited **and** none have significant 8-connected neighbour **then**

code number of leading insignificant samples via aggregation skip over any samples indicated as insignificant by aggregation

endif

while more samples to process in vertical scan **do**

if sample previously insignificant and unvisited **then**

code significance of sample if not already implied by run /* 1 binary symbol */

if sample significant **then**

code sign of sample /* 1 binary symbol */

endif

endif

endwhile

endfor

After every small block receives three coding passes in every bit-plane, the bit-stream will be generated. These bit-streams need to be reassembled to form the fine bit-stream. The second coding stage is for packaging the bit-streams from the first coding stage into data units called packets. The resulting packets are then assembled into the final bit stream. Fig.5 shows the two stage coding structure of EBCOT. Each packet consists of two parts: a head and a body. In this coding stage, many special features are assembled into the final bit-stream including the quality layer, resolution scalability, rate scalability, random access and region of interest coding.

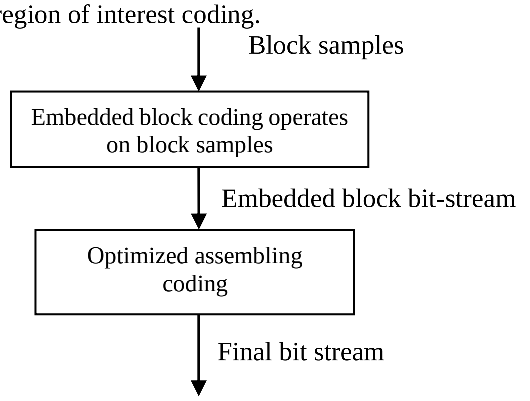

Fig.5 Two stage coding structure of EBCOT

VI. RESULTS AND COMPARISONS

The experimental results show the standard "Lena image", "Barbara image" and "Baboon image" 512 x 512 grayscale image compression with Peak Signal Noise Ratio (PSNR) parameters. We varied the bit rates from 0.1 to 0.9 bits per pixel (bpp). The performance of this algorithm is compared with respect to the existing SPIHT and JPEG2000. For this performance analysis we have considered PSNR and are calculated as follows.

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

By using the above formulae in the proposed algorithm the following parameters are calculated for the Lena image, Barbara image and Baboon image and are given in the following table 1, table 2, and table 3 respectively.

Table 1: Result analysis for Lena image of size 512 x 512

bpp	PSNR (dB)	
	SPIHT	Proposed Method
0.10	29.32	28.32
0.20	32.25	32.92
0.30	34.03	36.10
0.40	35.48	39.67
0.50	36.59	43.22
0.60	37.37	47.25
0.70	38.04	52.06
0.80	38.70	67.71
0.90	39.34	67.71

Table 2: Result analysis for Barbara image of size 512 x 512

bpp	PSNR(dB)	
	SPIHT	Proposed Method
0.10	21.08	23.45
0.20	22.27	26.86
0.30	23.33	30.69
0.40	24.20	35.52
0.50	25.02	40.06
0.60	25.82	43.85
0.70	26.54	47.85
0.80	27.29	50.39
0.90	27.94	50.39

Table 3: Result analysis for Baboon image of size 512 x 512

bpp	PSNR(dB)	
	SPIHT	Proposed Method
0.10	23.79	27.97
0.20	25.99	31.66
0.30	27.67	35.72
0.40	29.31	39.43
0.50	30.63	43.27
0.60	31.73	47.30
0.70	32.84	52.07
0.80	33.92	63.87
0.90	34.82	63.87

The PSNR values computed for the image Lena and Barbara are plotted in Fig.6 – Fig.7 for different values of bpp.

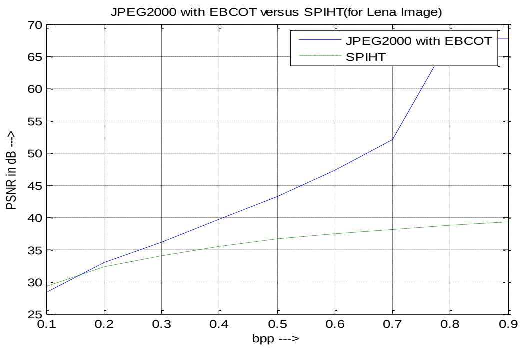

Fig.6 Performance comparison of JPEG2000 with EBCOT versus SPIHT for different bpp values for the image Lena

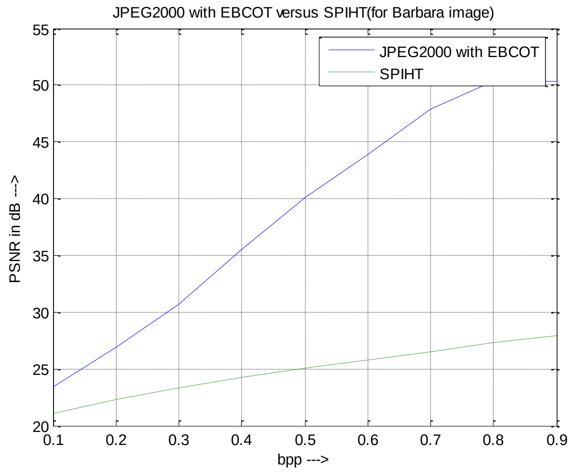

Fig.7 Performance comparison of JPEG2000 with EBCOT versus SPIHT for different bpp values for the image Barbara

VII. CONCLUSION

We are removing entropy coding in original JPEG2000 and replacing it by EBCOT. Experimental results of our scheme on standard images show that the proposed method is much better to that of SPIHT. Further, there is critical value in bpp above which the PSNR values obtained by our method reach saturation than SPIHT method.

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AUTHOR PROFILE

Dr. P. Sumitra. completed her Ph.D Degree in Computer Science from Mother Teresa Women's University, Kodaikanal, Tamil Nadu, India in the year 2013 and received her M.Phil Degree in Computer Science from Mother Teresa Women's University, Kodaikanal, Tamil Nadu, India in the year 2003. She published many International Journal paper, International Conference and National Conference. Her research areas include Digital Image Processing, Artificial Intelligence and Biometrics. She has 11 years of teaching experience in Self Finance institutions.

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