Efficient Image Compression and Transmission Using SPECK

N.B. Chopade, A. A. Ghatol and M. T. Kolte

***Abstract*—The necessity in image compression continuously grows during last decade. One of the promising & perspective approach in this are is discrete wavelet based, which uses subband coding concept. Multimedia data in uncompressed form requires considerable storage space, transmission bandwidth & computational time. This paper describes wavelet based embedded block, image coding algorithm Set Partioning Embedded Block Coder (SPECK). It uses recursive set partitioning procedure to sort subsets of wavelet coefficient by maximum magnitude with respect to threshold. An image block is divided in subblocks of equal size. Information regarding to image is coded according to decreasing order of importance. Because of low complexity & simplicity, this algorithm has very fast encoding and decoding which makes it very efficient in multimedia communication. The numerical results obtained using MATLAB shows that the output image has high value of Peak Signal to Noise Ratio with good compression ratio for low bit rate.**

***Index Terms*-- Discrete Wavelet Transform (DWT), SPECK, Peak signal to Noise Ratio (PSNR), Mean Square Error (MSE), Compression Ratio (CR).**

I. Introduction

VISIUL communication is becoming increasingly important with applications in several areas such as multimedia, communication, data transmission and storage of remote sensing images, satellite images, education, banking, medical, equity data etc. Meeting bandwidth requirements and maintaining acceptable image quality simultaneously is a challenge. Continuous rate scalable applications can prove valuable in scenarios where the channel is unable to provide a constant bandwidth to the application. Such decoders are particularly attractive because of their flexibility in allowing only one image or sequence to be stored in the database, avoiding the overhead of maintaining several coded images or sequences at different data rates. Hence, rate scalability allows one to encode once and decode on any platform fed by any data pipe [1]]. A specific coding strategy known as embedded

rate scalable coding is well suited for continuous rate scalable applications. In embedded coding, all the compressed data is embedded in a single bit stream and can be decoded at different data rates. The decompression algorithm receives the compressed data from the beginning of the bit stream up to a point where a chosen data rate requirement is achieved. A decompressed image at that data rate can then be reconstructed

and the visual quality corresponding to this data rate can be achieved. Common characteristics of most of images are that the neighboring pixels are highly correlated. The fundamental components of compression are reduction of redundancy and irrelevancy. Redundancy reduction aims at removing duplication from the image. Irrelevancy reduction omits parts of the signal that will not be noticed by the human visual system (HVS). Three types of redundancies can be identified, spatial redundancy, spectral redundancy and temporal redundancy. In still image, the compression is achieved by removing spatial redundancy and spectral redundancy [2-4]

II. Image Compression Process

The basic block diagram of compression & decompression of images are shown in Fig.1 & Fig.2. Compression process consists of transforming an input image using Discrete Wavelet transform, the quantization of the wavelet coefficients & encoding the coefficients. Decompression process involves decoding of the coefficients or compressed bit stream and application of inverse wavelet transform to reconstruct the image. Quantization introduces errors into the succeeding steps, hence the name is lossy compression. The calculation of the threshold value is one of the most important components of the lossy compression technique. For the high value of threshold the compression ratio is higher but image quality is poor & vice versa [4].

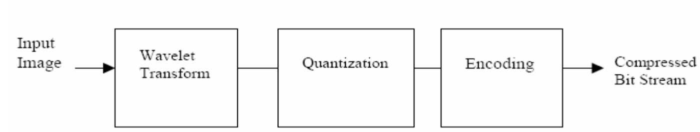

Fig.1. Image Compression process

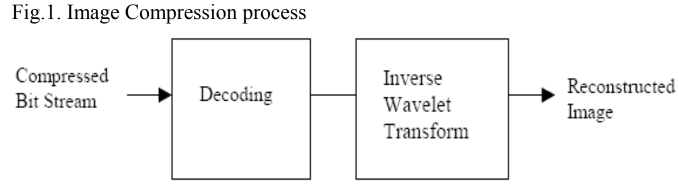

Fig. 2. Decompression Process

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III. WAVELET TRANSFORM

A. Continuous Wavelet Transform

The Continuous Wavelet Transform (CWT) is represented by equation (1), where f (t) is the signal to be analyzed. $\psi_{a,b}$(t) is the mother wavelet or the basis function. Parameter '*a*' is a scaling factor and '*b*' is shifting factor. All the wavelet functions used in the transformation are derived from the mother wavelet through translation or shifting and scaling or compression [3,6]

$$CWT(a,b) = \langle \psi^*_{a,b}(t), f(t) \rangle = \int_{-\infty}^{\infty} \psi^*_{a,b}(t) f(t) dt \quad (1)$$

A basis function $\psi_{a,b}$(t) is seen as filter bank impulse response. Through continuous wavelet transform analysis, a set of wavelet coefficients {CWT (*a*, *b*)} are obtained. These coefficients indicate how close the signal is to a particular basis function.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right) \quad (2)$$

The mother wavelet has to satisfy the following admissibility condition

$$C_\psi = \int_{-\infty}^{\infty} \frac{|\psi(\omega)|^2}{\omega} d\omega < \infty \quad (3)$$

The function *f*(*t*) can be recovered from its transform by equation (4)

$$f(t) = \frac{1}{C_\psi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} CWT(a,b) \psi_{a,b}(t) \frac{da db}{a^2} \quad (4)$$

B. Discrete Wavelet Transform

The Discrete Wavelet Transform (DWT), which is based on sub-band coding, is found to yield a fast computation of Wavelet Transform. It is easy to implement and reduces the computation time and resources required. In the case of DWT, a time-scale representation of the digital signal is obtained using digital filtering techniques [4]. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales. The discretization is performed by setting a = a_0^j and b = k a_0^j b_0 for j, k $\in$ Z. where, a_0 >1 is a dilated step and b ≠ 0 is a translation step. The family of wavelets then becomes

$$\psi_{j,k}(t) = a_0^{-j/2} \psi(a_0^{-j/2} t - kb_0) \quad (5)$$

and the wavelet decomposition of a function *f* (*t*) is

$$f(t) = \sum_j \sum_k D_f(j,k) \psi_{j,k}(t) \quad (6)$$

Where 2-dimensional set of coefficients D_f (*j*,*k*) is called DWT of given function *f*(*t*) [6].

IV. FILTER BANK STRUCTURE

A 2D DWT can be implemented as a filter bank by combining Analysis & synthesis stages together. The design strategy for the filters in the filter bank is such that it leads to Perfect Reconstruction. A 2D DWT of an image is obtained by using Low pass h_0 (m) & High pass h_1 (m) filters successively shown in fig 3. An image component obtained by low pass filtering of rows & columns is LL image. Low pass filtering of rows & high pass filtering of columns, gives LH image component. High pass filtering of rows & low pass filtering of columns gives LH image component & HH component is the result of high pass filtering of rows & columns [4-6].

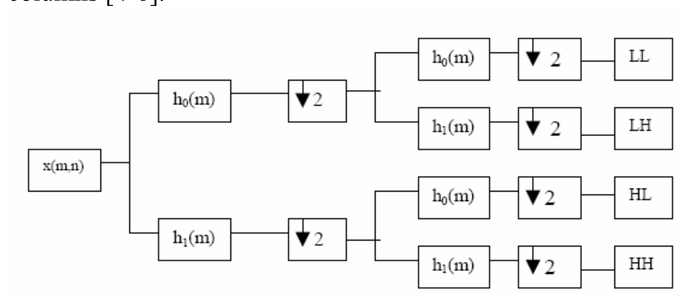


Fig 3. Subband Decomposition of an Image

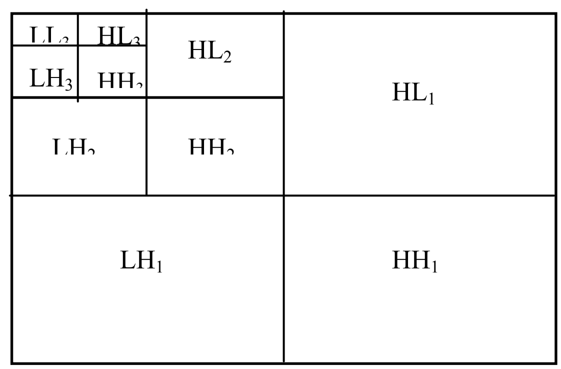


Fig4. Pyramidal structure of 3-level wavelet decomposition

V. THE PEAK SIGNAL TO NOISE RATIO

The PSNR metric is a well utilized and industry accepted metric for the objective quantification of image compression algorithm If $x_i, \hat{x}_i$ are the input & reconstructed pixel values in the image respectively, M is the maximum peak-to-peak value in the image (typically 256 for 8 bit image). The PSNR is a function of the mean squared error. A good PSNR performance is a prerequisite for any modern compression algorithm [7]

$$MSE = \sum_{i=0}^{N-1} \left| x_i - \hat{x}_i \right|^2 \qquad (7)$$

$$PSNR = 10 \log_{10} \left(\frac{M^2}{MSE} \right) \qquad (8)$$

VI. THE SPECK ALGORITHM

The algorithm includes encoder and decoder, which implements initialization, sorting pass, refinement pass & quantization steps [10]. Threshold selection & Pixel significance in an entire set (T) of pixels are carried out using equation (9).

$$\max_{(i,j)\in T} \left\{ \left| C_{i,j} \right| \right\} \geq 2^n \qquad (9)$$

The algorithm makes use of rectangular regions of image. These regions or sets are called as sets of type *S*. The dimension of a set *S* depends on the dimension of the original image and the subband level of the pyramidal structure at which the set lies.

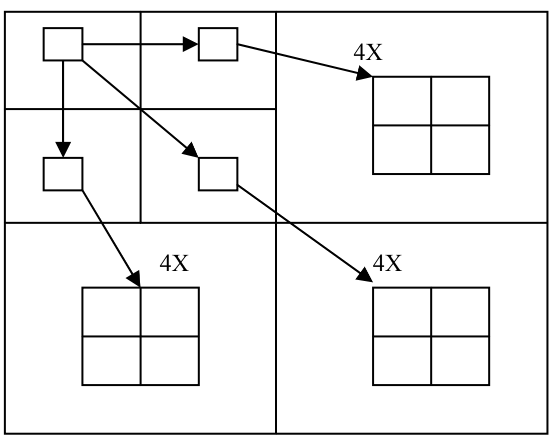


Fig 5. Parent offspring dependencies in tree based organization in wavelet transform

During the course of the algorithm, sets of various sizes will be formed, depending on the characteristics of pixels in the original set. Note that a set of size 1consists of just one pixel. The other types of sets used in the SPECK algorithm are referred to as sets of type *I*.

The algorithm maintains two linked lists: *LIS* - List of Insignificant Sets, and *LSP* - List of Significant Pixels. The LIS contains sets of type *S* of varying sizes, which have not found significant against a threshold *n* while LSP obviously contains those pixels that have tested significant against n. Use of multiple lists will speed up the encoding/decoding process. Following flow chart describes the algorithm [10-15].

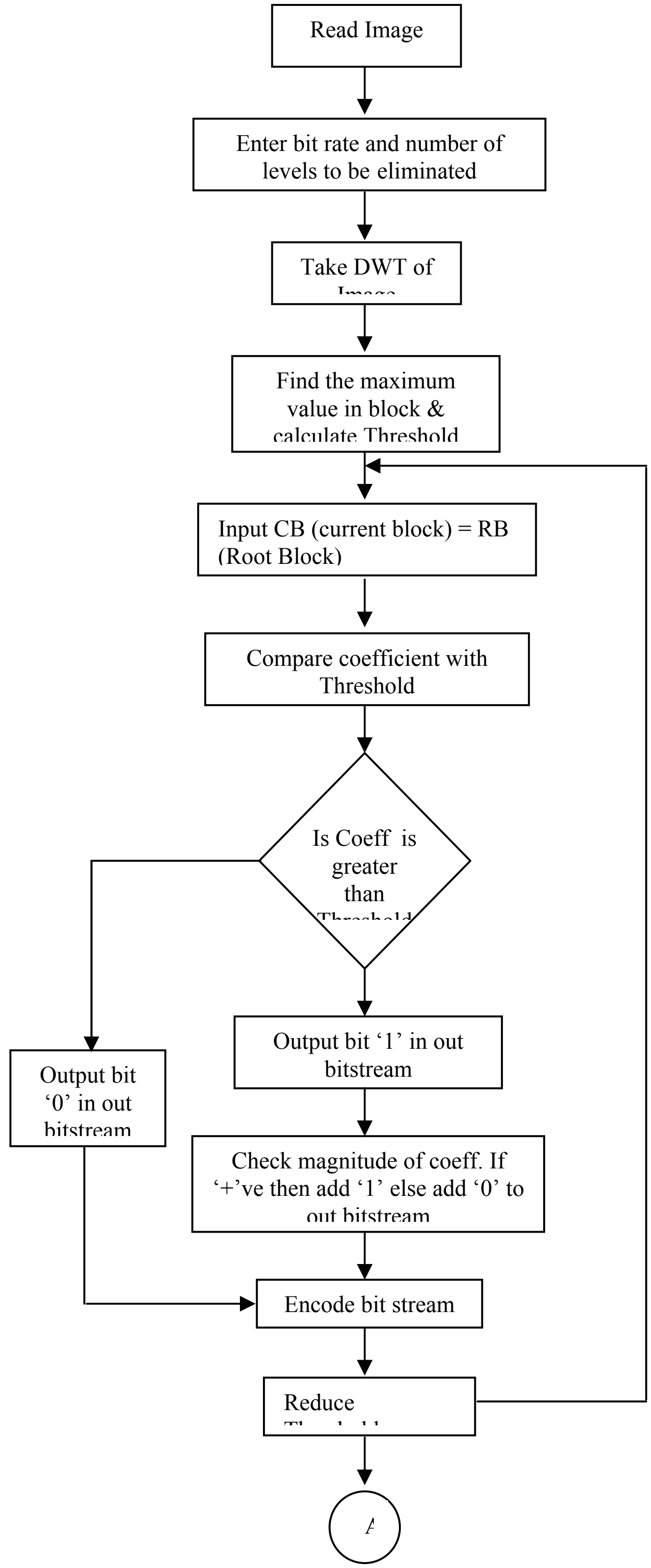


Fig 6. Flow chart of Encoder

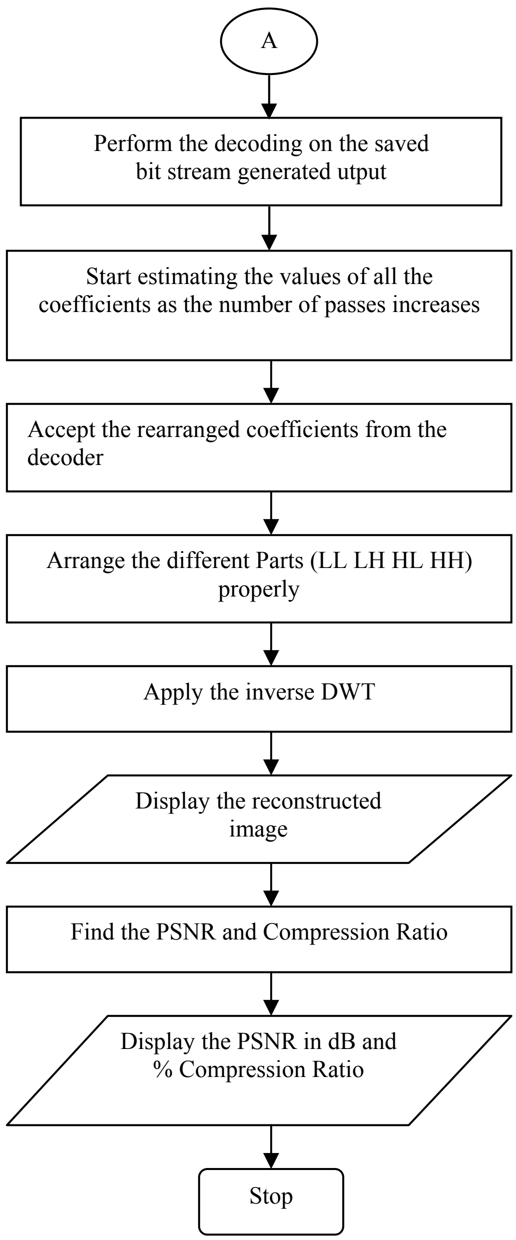


Fig 7. Flow chart of Decoder

TABLE I
PSNR AND COMPRESSION RATIO VALUES FOR DIFFERENT IMAGES

Image	Bit rate	PSNR	MSE	Compression Ratio
COIN (256X256)	0.25	28.82	44.26	84.20
	0.50	29.75	43.17	83.11
	0.75	31.82	42.72	81.12
	1.00	32.81	41.28	78.23
LENA (512X512)	0.25	26.12	42.72	84.27
	0.50	28.02	41.27	82.25
	0.75	29.68	39.98	78.45
	1.00	31.43	36.12	74.20

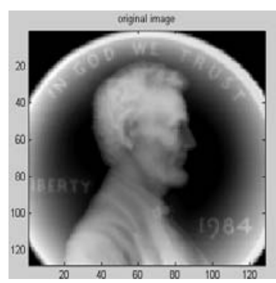
TABLE II
PSNR PERFORMANCE OF DIFFERENT CODING ALGORITHMS

Bit Rate	EZW PSNR dB	SPIHT PSNR dB	SPECK PSNR dB	EBCOT PSNR dB
0.25	26.84	28.64	28.85	25.93
0.50	27.98	30.23	29.75	26.74
0.75	29.26	31.68	30.89	28.17
1.00	31.53	32.46	32.81	30.18

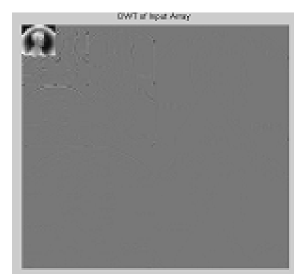
VII. EXPERIMENTAL RESULTS

The SPECK coding / decoding algorithm has been implemented in MATLAB and tested on images of different of size & type. Biorthogonal 9/7 wavelet filters are used. The DWT level is kept equal to three. The experimental results are presented for images of different types & size in Table1, in terms of PSNR values & compression ratio for various bit rates. The PSNR performance of this algorithm is compared with the state of the art coding & compression algorithm like EZW, SPIHT, EBCOT & the numerical results are presented in Table 2.

1.Image**: COIN**



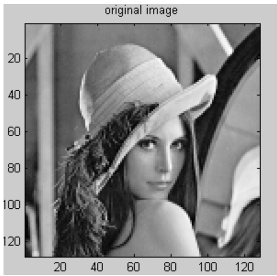
a) Original Image



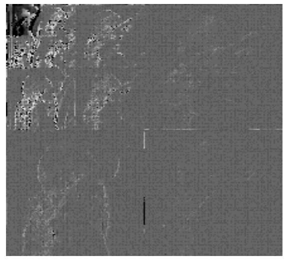
b) DWT of an Image

c) Reconstructed Image (0.25 bpp)

2.Image**: LENA**



d) Original Image



e) DWT of an Image

f) Reconstructed Image (0.75 bpp)

Fig 8. Original & Reconstructed Images with the SPECK

VII. CONCLUSION

In this paper discrete wavelet based SPECK image coding algorithm has been presented. The algorithm has been implemented in MATLAB. The designed codes are tested with images of different size & type. From the experimental results it has been found that increasing bit rate, PSNR increases & compression ratio & MSE decreases. The SPECK coding scheme provides excellent results compared to EZW, SPIHT and EBCOT methods.

VIII. REFERENCES

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IX. BIOGRAPHIES

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