Comparative performance of Embedded Coders at High Quality

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***Abstract* — Embedded Zerotree Wavelet (EZW) coder has become very popular in image compression applications, owing to its simplicity and high coding efficiency. In this paper, we first illustrate the Shapiro algorithm (EZW). In second, we combine the discrete cosine transform (DCT) with an embedded zerotree quantizer in order to obtain the Xiong et al. algorithm (EZDCT). Our aim is to improve the bit rate gotten by EZDCT algorithm while changing the resolution level and to make a comparison with the EZW algorithm. The experiments show that the DCT-based embedded image coder gives higher peak signal-to-noise (PSNR) than Joint Photographic Expert Group (JPEG) and almost similar than Shapiro's EZW coder. Likewise, our contribution also gave an improvement to the results gotten by Zhao et al.**

***Index Terms* — Image coding, embedded coding, wavelet transform, discrete cosine transform.**

I. INTRODUCTION

Transform coding is one of the most efficient methods for image compression. In a transform based compression system two-dimensional images are transformed from the spatial domain to the frequency domain. An effective transform will concentrate useful information into a few of the low frequency transform coefficients. Human visual system is more sensitive to energy with low spatial frequency than with high spatial frequency. Therefore compression can be achieved by quantizing the coefficients so that important coefficients (low frequency coefficients) are transmitted and remaining coefficients are discarded. Very effective and popular ways to achieve compression of image data are based on Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT).

Recently the application of wavelets in image compression has received significant attention and several very efficient wavelet-based image compression algorithms have been proposed. This is due to the fact that the wavelet transform can provide a multi-resolution representation for an image or a signal with localization in both time and frequency domains. In addition, the coarse-to-fine representation of images matches the characteristics of the human visual system, and makes it possible to achieve both high compression ratio and good subjective quality for the decoded image for image compression. EZW (Embedded Zerotree Wavelets) [1] uses a zerotree data structure to characterize the selfsimilarity of zeros across different scales. It can provide better image quality than DCT especially on higher compression ratio. But the implementation of the DCT is less expensive than that of the DWT. For example, the most efficient algorithm for 2-D 8x8 DCT requires only 54 multiplications [2] while the complexity of calculating DWT depends on the length of wavelet filters, which is at least one multiplication per coefficient. In this context, we give a comparative study between EZW and EZDCT (Embedded Zerotree Discrete Cosine Transform)[3] where the DCT is coupled with an embedded zerotree quantizer. In our study, we propose to vary the size of DCT blocks of 4×4 up to 64×64 instead of 8×8 only in order to have several resolution levels.

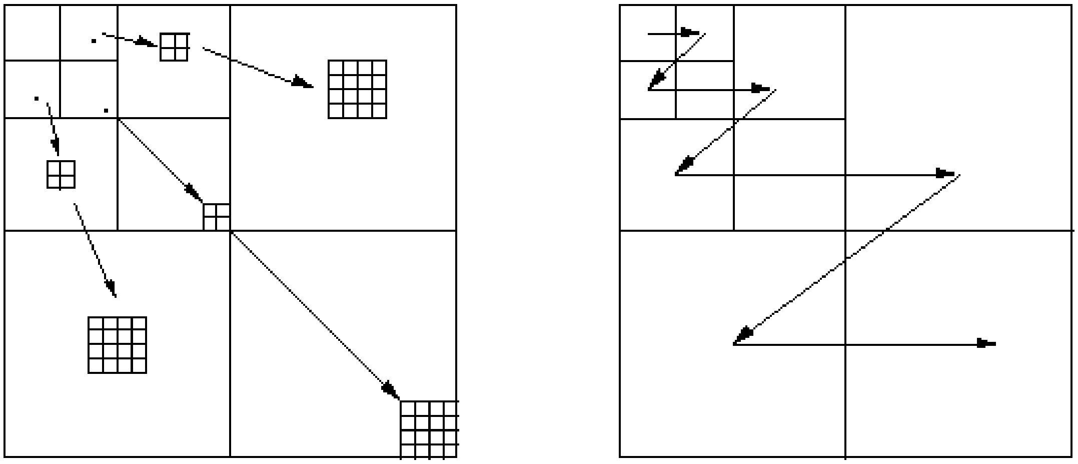
In this paper, firstly, we present the EZW algorithm in section II. Secondly, we exploit this algorithm in DCT-based image coding scheme with a new reorganization of DCT coefficients in section III. Finally, experimental results and performance comparison are provided in Section V. The last section concludes the paper.

II. EZW CODING SCHEME

The Embedded Zerotree Wavelet (EZW) coding scheme was proposed by Shapiro [1]. As the name suggests, this coding method has the embedding property. Essentially, there are three key elements to the EZW scheme:

1. The wavelet transform [4] is used to form a hierarchical subband decomposition of an image.
2. The absence of significant information across scales is predicted by exploiting the self-similarity inherent in images.
3. Successive approximation quantization is combined with arithmetic coding [5] [6] to produce the compressed bit stream.

The second point above is arguably the most important. The EZW scheme encodes the wavelet transform coefficients in bit significance order.



(a) (b)

Fig. 1(a) Structure of zerotrees, and 1(b) Scanning order of subbands for encoding

Normally, this would also require that the coefficient positions be explicitly coded. By predicting the absence of significant information across scales, however, the EZW scheme is able to avoid encoding individual coefficient positions explicitly. Not having to explicitly encode the position of each coefficient saves bits and leads to excellent compression results. The way of constructing a zerotree is as follows:

A. Initialization

Compute the wavelet transform of the image [4]. Determine the threshold 'T_0' so that it is equal to the greatest power of two lower than the maximum value of the wavelets coefficients.

$$T_0 = 2^{[\log_2(c_{\max})]} \quad (1)$$

B. Dominant Pass

We traverse the wavelets coefficients according to the way represented on fig. 1(b), so that the "zerotree" are most effective possible (fig. 1 (a)).

For each coefficient we affect one of the four following symbols by comparing them with the current threshold T_i:

1. Positive Significant (POS): if the absolute value of the coefficient is greater than the threshold T_i and positive sign.

2. Negative Significant (NEG): if the absolute value of the coefficient is greater than the threshold T_i and negative sign.

3. Isolated Zero (IZ): if the absolute value of the coefficient is lower than the threshold T_i having one or more descendants which are not negligible in front of T_i.

4. Zerotree Root (ZTR): if the value of the coefficient is lower than the threshold T_i having only negligible descendants.

Moreover, all the descendants coefficients of a coefficient which has symbol ZTR are not coded. When the decoder receives a coefficient noted ZTR it will know that all the descendants are negligible. We transmit only for part of the coefficients the four symbols above.

C. Subordinate Pass

For all the significant values given in the preceding stage, we emit the bit corresponding to 2^{i-1} to increase the precision of the transmitted significant values.

Subordinate pass is used to make the coefficients significant at the current stage negligible at the next stage to increase the chances to have "zerotree".

We start again the algorithm at step B on the residue of the image by incrementing 'i' of one and by dividing the threshold 'T_i' by two. We reiterate the process until the quality standard of the image is reached or which the transferable number of bits is exceeded.

III. EZDCT Coding SCHEME

Typical images can be described as a set of smooth surfaces delimited by edge discontinuities. This is shown in the DCT domain by two facts.

1. Signal energy due to smooth regions is compacted mostly into DC coefficients, thus resulting in negligible contributions to coefficients in the higher frequency bands.

2. Due to the small compact support associated with DCT, edges can only contribute energy to a small number of AC coefficients.

The simplest form DCT-based encoder can be thought of as essentially compression of a stream of 8x8 blocks of image samples. Each 8x8 block makes its way through each processing step, and yields output in compressed form into the data stream.

TABLE I

PSNR RESULTS IN (DB) FOR DIFFERENT SCALES AND DIFFERENT RATES OBTAINED WITH EZW AND EZDCT

Scale			PSNR (dB)									
			EZW					EZDCT				
			2	3	4	5	6	2	3	4	5	6
Barbara	Bitrate(bpp)	0,125	22,06	24,06	24,39	24,48	24,48	22,26	24,26	25,39	25,80	25,54
		0,25	25,26	26,98	27,13	27,17	27,16	24,33	27,01	28,09	28,44	27,90
		0,50	29,55	30,89	31,02	31,03	31,03	27,45	30,87	31,73	31,94	31,23
		0,75	31,95	33,77	34,21	34,24	34,26	30,72	33,12	35,13	35,14	34,58
		1,00	35,25	35,67	35,80	35,81	35,82	33,22	35,69	36,51	36,63	35,83
Peppers	Bitrate(bpp)	0,125	23,65	29,31	29,55	29,60	29,59	24,32	27,74	29,15	29,02	28,53
		0,25	29,63	32,14	32,27	32,28	32,27	28,73	31,32	31,83	31,48	30,91
		0,50	33,59	34,45	34,49	34,48	34,48	32,51	34,18	34,18	33,94	33,25
		0,75	35,02	35,25	35,26	35,24	35,24	34,48	35,03	35,09	34,88	34,47
		1,00	36,02	36,74	36,83	36,82	36,82	35,29	36,11	36,30	35,98	35,49
Lena	Bitrate(bpp)	0125	24,30	29,68	30,08	30,18	30,19	25,34	28,27	29,64	29,79	29,43
		0,25	30,61	32,87	33,08	33,13	33,13	28,94	32,00	32,82	32,83	32,33
		0,50	35,13	36,14	36,23	36,24	36,24	33,09	35,77	36,11	36,02	35,53
		0,75	37,07	38,00	38,20	38,24	38,26	35,90	37,26	37,93	37,89	37,27
		1,00	39,23	39,43	39,48	39,48	39,48	37,42	39,23	39,44	39,34	38,97
Goldhill	Bitrate(bpp)	0,125	25,49	27,74	27,93	27,98	27,99	25,06	27,20	27,88	28,01	27,99
		0,25	28,86	29,98	30,24	30,26	30,26	27,98	29,32	30,09	30,31	30,24
		0,50	31,65	32,14	32,24	32,28	32,28	30,94	31,85	32,35	32,42	32,34
		0,75	33,97	34,14	34,18	34,20	34,20	33,17	34,00	34,23	34,21	34,08
		1,00	35,04	35,29	35,35	35,37	35,37	34,49	35,13	35,43	35,41	35,27

In [3], block-based DCT coding can treat as a depth-3 tree of coefficients. After reorganization can be further utilized to DCT-based coder in order to obtain better compression performance as EZW did in the wavelet domain. The EZDCT algorithm is as follows:

1. An input image is first partitioned into $n \times n$ blocks, where $n = 2^L$, $L > 0$.
2. Each block is then transformed to the DCT domain [7] and can be taken as an L-scale tree of coefficients with $3 \times L + 1$ subbands decomposition.
3. After that, the same subbands for all DCT blocks are grouped and put onto their corresponding positions. Fig. 2 demonstrates a DCT block taken as three-scale tree structure with ten-subband decomposition.
4. An embedded zerotree quantizer is then applied to quantize the tree-structured DCT coefficients as was done to the wavelet coefficients in [1].

IV. EXPERIMENTAL RESULTS AND PERFORMANCE COMPARISON

The performances of our algorithms are evaluated on several standard images. All the images are of 512×512 pixels, 8 bit/pixel. As usual, the distortion is measured by peak signal-to-noise ratio (PSNR) defined as:

$$PSNR(dB) = 20\log_{10}\frac{255}{RMSE} \tag{2}$$

Where RMSE is the root mean-square error between the original and reconstructed images.

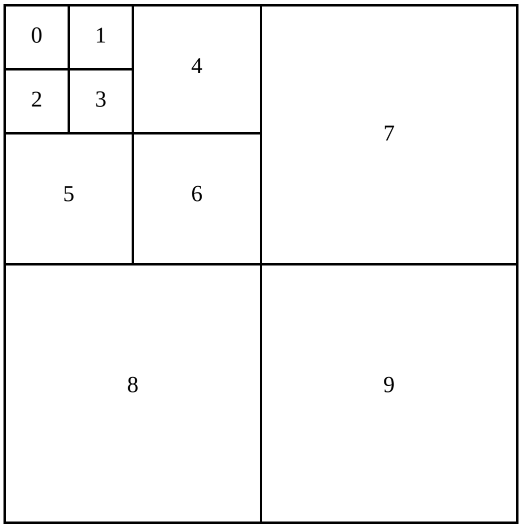
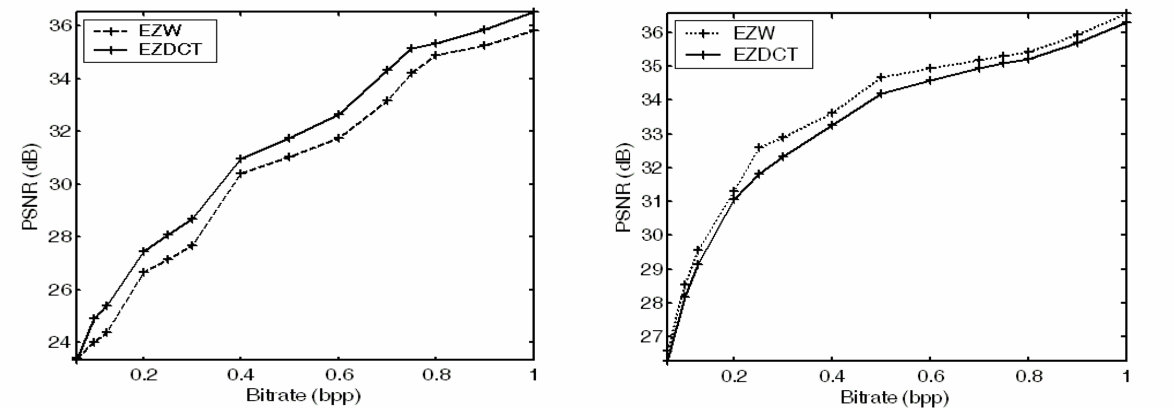


Fig. 2 8×8 DCT block taken as three-scale tree with ten-subband decomposition.

Table I shows EZW and EZDCT coding results with different scales and different rates. Fig. 3 compares for the Barbara and the Peppers images, the peak-SNR vs. bits per pixel results obtained by an EZW coder and an EZDCT coder when four scales dyadic are used.

Similarly, Fig. 4 and Fig. 5 show performance of the two coding algorithms for the same images and the same scale at 0,25 bpp and 0,125 bpp respectively.

Note that the 7/9 bi-orthogonal filters in [1] are used in EZW case.



(a) (b)

Fig. 3 Comparison results between EZW and EZDCT at scale 4 (a) Barbara (b) Peppers.

(a) (b) (c)

Fig. 4 Performance of the two coding algorithms at scale 4 and 0,25 bits/pixel (a) Original 512×512 8bpp "Barbara" image, (b) PSNR = 27,13 dB (EZW), (c) PSNR = 28,09 dB (EZDCT).

(a) (b) (c)

Fig. 5 Performance of the two coding algorithms at scale 4 and 0,125 bits/pixel (a) Original 512×512 8bpp "Peppers" image, (b) PSNR = 29,55 dB (EZW), (c) PSNR = 29,15 dB (EZDCT).

For Barbara image, EZDCT is better than EZW, while for Peppers image, EZW is slightly better than EZDCT. According the results obtained, we can say that the block-based DCT by proper reorganization and representation of its coefficients can have the similar characteristics to wavelet transform, such as energy compaction, cross-subband similarity, decay of magnitude across subband, etc. Also, if we rise the level of decomposition at four and five, the compression quality (PSNR) will be improved by 1,18 dB and 1,4 dB respectively for Barbara image compared with [3]. The increase of the level of decomposition to four and to five permits us to have some zerotree in more without affecting the DC components.

For all images the PSNR obtained at each bitrate is found to be better than JPEG coders [7] and our contribution also brought an improvement in comparison to [8].

Generally speaking, the DCT decomposition based image coder has comparable PSNR performance with wavelet coder, yet with lower complexity.

V. CONCLUSION

We presented results from a comparative study of wavelet-based and DCT-based image compression systems using objective PSNR quality measures. These two methods use an embedded zerotree structure.

In this paper, we show that the block-based DCT with proper organization and representation of its coefficients can have similar characteristics to wavelet transform. The experimental results show that the DCT-based embedded image coder presents a low complexity that is better than JPEG and almost similar than Shapiro's EZW coder. DCT is capable of delivering much better performance than JPEG, just as it is for the wavelet transform.

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