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Postprocessing Techniques for Absolute Moment Block Truncation Coding*

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Abstract

Block Truncation Coding uses a two-level moment preserving quantizer that adapts to local properties of the images. It has the features of low computation load and less memory request while its bit rate is only 2.0 bits per pixel. A more efficient algorithm, the absolute moment BTC (AMBTC) has been extensively used in the field of signal compression because of its simple computation and better MSE performance. We propose postprocessing methods to further reduce the entropy of two output data of AMBTC including the bit map and two quantization data (a, b). The block of 2 x 4 bit map is packaged into a byte-oriented symbol. The differential entropy can be reduced from 0.965 bpp to 0.917 bpp in average for our test images. The two subimages of quantization data (a, b) postprocess by the Peano Scan. This postprocess can further reduce differential entropy about 0.4 bit for a 4x4 block. By applying arithmetic coding, the total bit reduction is about 0.3~0.4 bpp. The bit rate can achieve 1.6~1.7 bpp with the same quality of traditional AMBTC.

Keywords: Block Truncation Coding, AMBTC, bit map, byte-oriented, quantization data, Peano Scan

1. Introduction

Block Truncation Coding (BTC) [1] is a simple and effective coding technique. In the original form, the image is at first divided into a series of nonoverlapping blocks of pixels, and a two-level quantizer is independently designed for each block. Both the quantizer threshold and the two reconstruction levels are varied in response to the local statistics of a block. It has the advantages of requiring low computational complexity and preserving the edge. A more efficient algorithm, the absolute moment BTC (AMBTC) [2] has been extensively used in the field of signal compression because of its simple computation and better MSE performance. The compression ratio for 4x4 blocks is 4:1. The bit rate achieved only 2 bpp for both standard BTC and AMBTC methods. In order to further reduce the bit rate, several variants BTC which approach better compression performance have been proposed during the past 15 years.[3] In this paper, we propose postprocessing methods to further reduce the entropy of two output data of AMBTC including the bit map and two quantization data (a, b). The bit map is packaged into byte-oriented symbols for every 2x4 bit map. The differential entropy can be reduced from 0.965 bpp to 0.917 bpp in average for our test images.

The remainder of this paper is organized as follows. Section 2 gives a brief description of basic background theory. Section 3 describes the scheme of quantization data (a, b) reduction and the new byte-oriented packaged method of bit map. Simulation results are given in section 4 and finally, conclusions are drawn in Section 5.

2. Background

2.1 Block Truncation Coding

The image compression technique Block truncation coding (BTC) was proposed by Edward J. Delp and O. Robert Mitchell on 1979.[1] It uses a two-level nonparametric quantizer that adapts to local properties of the image. The quantizer that shows great promise is one which preserves the local sample moments. The main advantages of BTC are less data storage and low computation.

In Block Truncation Coding, an image is divided into $n \times n$ (typically, 4×4) nonoverlapping blocks of pixels, and each block needs a two-level quantizer independently. Both the quantizer threshold and the two reconstruction levels are varied in response to the local statistics of a block. Therefore, encoding is the generating of the two reconstruction levels and a block consists of an $n \times n$ bit map indicating the reconstruction level associated with each pixel for one image. Decoding is a process that reconstruct the image by placing the corresponding appropriate reconstruction value at the pixel location as the bit map representation. Fig. 1 shows the diagram of the basic BTC scheme.

Many reported BTC schemes make use of moment-preserving quantizers. These quantizers preserve a limited number of moments of a block, mean and variance. Let the image block be of $m = n \times n$, and $X_1, X_2, \ldots, X_m$ be the pixel values in the original picture block. Then the first and second sample moments and the sample variance are

$$\overline{X} = \frac{1}{m}\sum_{i=1}^{m} X_i \qquad (1)$$

$$\overline{X^2} = \frac{1}{m}\sum_{i=1}^{m} X_i^2 \qquad (2)$$

$$\overline{\sigma^2} = \overline{X^2} - \overline{X}^2 \qquad (3)$$

As a one-bit quantizer, there is a threshold, X_{th}, and two output levels, a and b, such that

$$\begin{cases} if\ X_i \geq X_{th}\ \ output = b \\ if\ Xi < X_{th}\ \ output = a \\ \quad for\ i = 1, 2, \ldots, m \end{cases} \qquad (4)$$

Let q be the number of X_i's that have values greater than $X_{th}\ (= X)$. Then, to preserve $\overline{X}$ and X^2, we have

$$\begin{cases} m\overline{X} = (m-q)a + qb \\ m\overline{X^2} = (m-q)a^2 + qb^2 \end{cases} \qquad (5)$$

Solving for a and b, we have

$$a = \overline{X} - \overline{\sigma}\sqrt{\left[\frac{q}{m-q}\right]}$$
$$b = \overline{X} + \overline{\sigma}\sqrt{\left[\frac{m-q}{q}\right]} \qquad (6)$$

The disadvantage of the quantizer is that it needs the squaring and square root operations. An approach with simple operation is absolute moment block truncation coding (AMBTC), in which the quantizer is designed to preserve the absolute moments. The absolute moment block truncation coding preserve the mean and the first absolute central moment of a $n \times n\ (m = n \times n)$ block. The first absolute central moment is defined as

$$\alpha = \frac{1}{m}\sum_{i=1}^{m} \left| X_i - \overline{X} \right| \qquad (7)$$

The reconstruction levels that preserve X and α are therefore

$$a = \overline{X} - \frac{m\alpha}{2(m-q)} \qquad (8)$$

$$b = \overline{X} + \frac{m\alpha}{2q} \qquad (9)$$

2.2 Peano Scan

Incorporating an efficient scan strategy into an encoding scheme can achieve higher compression performance. The Peano Scan [4], a multidimensional space filling curve, visits adjacent pixels of an image both in horizontal and vertical directions in a prescribed sequence.

The Peano Scan is self-similar and continuous, and also can be used in real time for on-line visual communication systems. Theoretically, any Peano Scan whose size is large than 4 and is a power of two can be generated by a 4 x4 basic element as shown in Figure 2. The Peano Scan may be applied in cases where the scanning order is important for an image transformation, such as data compression or halftoning, because transformation of a pixel affects the pixels. Many reports had applied the Peano Scan to data compression such as fractal based image coding [5], LOT scheme [6], and VQ [7]. To our best acknowledge, no one has applied the Peano Scan to the BTC coding. In this paper, we use the peano scan as postprocess to code the two quantization data (a, b) subimages.

3. Bit Rate Reduction schemes

3.1 Reduction the Quantization Data

In AMBTC coding, we can get two subsampled images - high-mean and low-mean subimages. For a 512 x 512 input image with 4 x 4 blocks, The size of subimage is 128 x128. Several methods for coding the quantization data have been proposed in the literature including the fixed number of bits [1], vector quantization [8], DCT [9], and lossless coding [10]. The subimages have more details and important features that must be preserved. Therefore, the use of a lossless image compression scheme is a good choice.

We take the Peano Scan as postprocess for the two subimages. The original and scanned subimages are shown in Fig. 3. Then, we apply simple DPCM scheme to reduce the entropy of the scanned subimage. Comparing to the pure DPCM without any postprocess, the improvement of bit rate reduction is effective.

3.2 Bit Map Reduction

In the original AMBTC method, both the bit map and quantization data of a block need 16 bits each. The bit map occupies about 50 % of the output code. Those bit maps exit high correlation. Although some schemes have been made to compress the bit map, the subjection results are not quite satisfactory. Pasi and Timo [3] classified those schemes to (1) skipping the bit map, (2) prediction technique, (3) filtering technique, (4) vector quantization, (5) Interpolation and (6) entropy coding. In our method, each 4 x 4 bit-map is first divided into two parts called high-map and low-map. Then, both the high-map and low-map are packaged into a byte-oriented symbol. Therefore the simple DPCM scheme is apply to reduce the redundancy and coded by lossless method. This postprocess of bit map can further reduce the differential entropy efficiently. The processes are indicated in Fig. 4. Fig. 5 shows the original bit map and byte-oriented image of Lena.

4. Experiment results

In our coding simulation for AMBTC , we considered five monochrome images including the two versions of Lena: the first one is the green-component (G), of the original RGB-image, while Lenna is the luminance component (Y) [3]. There exits some confusion in the past literatures in using the "Lena" image. Some authors compare their results with the other papers directly, but they may simulate on different versions of Lena. We want to indicate that "Lena" is not "Lenna". We should distinguish them in future development and application for image process. Table 1 shows the results of tested images coded by AMBTC. In AMBTC coding, there are about 1 dB difference between 'Lena' and 'Lenna'. To reduce the bit map of AMBTC, our byte-oriented method can reduce 8.3% bit rate for the bit map. The results of bit map coding are listed in Table 2. The reduction of quantization data can achieve 28.8 % with original quantization data of AMBTC. The postprocess of Peano Scan can get about 3.5% improvement as shown in Table 3. By applying arithmetic coding, the total bit rate reduction is about 0.3-0.4 bpp. The bit rate can achieve 1.6-1.7 bpp with the same quality of traditional AMBTC. Table 4 shows the results of byte-oriented bit map and Peano scanned (a, b) coded by the Arithmetic coding.

5. Conclusions

A new approach to AMBTC scheme based on the Peano scan and byte-oriented technique has been proposed. The results presented have shown the effectiveness of the new schemes. A comparison with the traditional AMBTC indicates that the performance of these processes can further reduce the bit rate about 0.35 bpp without losing any quality of reconstructed image.

6. References

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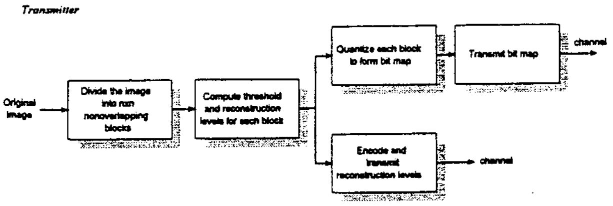


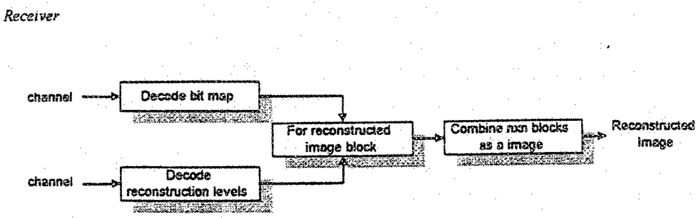
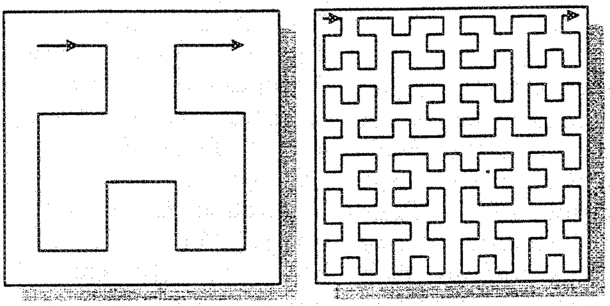


Figure 1 BTC diagram.



4x4 block Peano Scan

16x16 block Peano Scan

Figure 2 Examples of 4x4 and 16x16 Peano Scan.

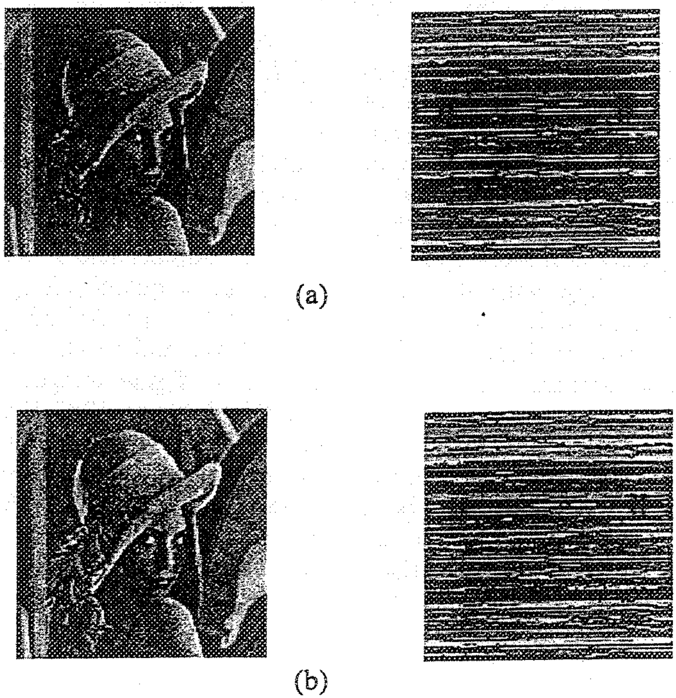
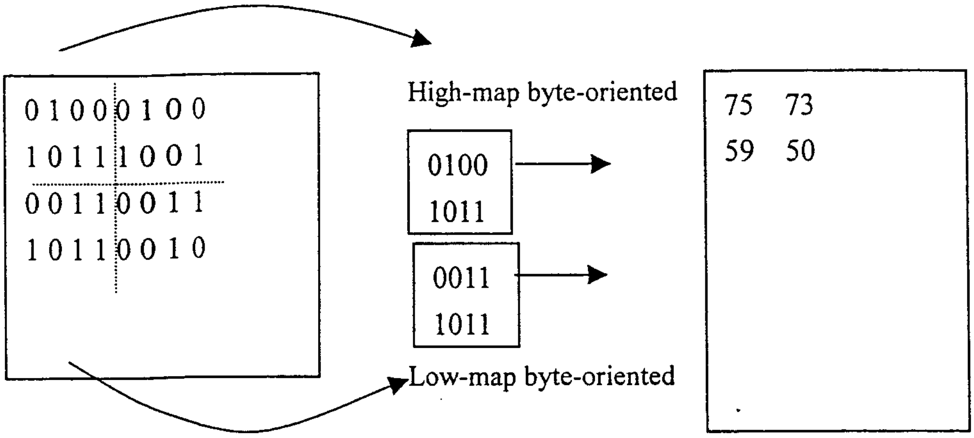


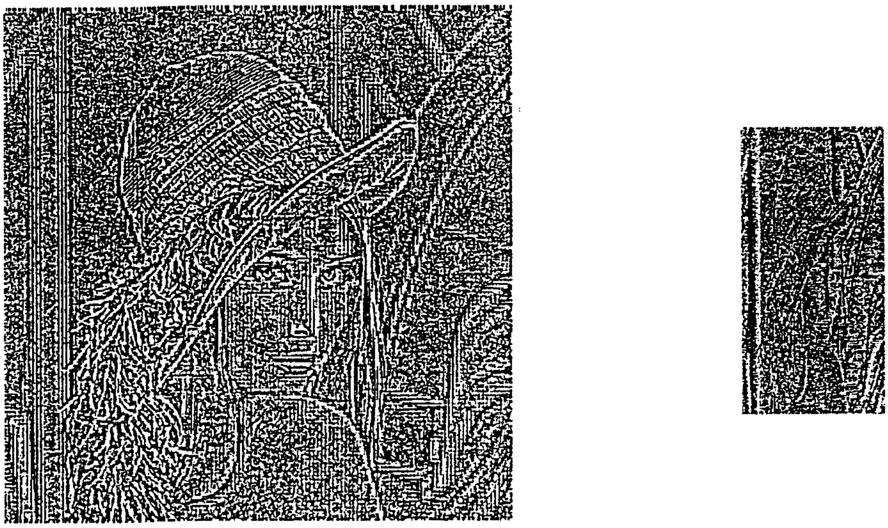
Fig. 3 Subimages of quantization data for Lena image, (a) the lower output data a (b) the higher output data b. The right subimages are scanned by Peano scan.



(a) original bit-map

(b)byte-oriented symbols

Fig. 4 Examples of byte-oriented (a) original bit-map (b)byte-oriented symbols



(a)

(b)

Fig. 5 The bitmap of Lena, (a)512 x 512 original bitmap(binary image), (b) 128 x 256 byte-oriented image(256 gray levels).

Table 1
Results of Tests images by BTC and AMBTC Coding (bit-rate 2.00 bpp)

	BTC		AMBTC	
	MSE	PSNR	MSE	PSNR
Lena	43.69	31.73	40.64	32.04
Lenna	33.30	32.91	31.05	33.05
Airplane	54.95	30.73	51.26	31.03
Pepper	48.49	31.27	45.04	31.60
Baboo	180.17	25.57	163.51	26.00

Table 2

Results of Bit Map Coding

	Pure DPCM entropy		DPCM entropy with Byte-	
	Bpp	bit reduce %	bpp	Bit reduce %
Lena	0.985	1.5 %	0.915	8.5 %
Lenna	0.982	1.8 %	0.901	9.9 %
Airplane	0.931	6.9 %	0.894	10.6 %
Pepper	0.993	0.7 %	0.946	5.4 %
Baboo	0.933	6.7 %	0.929	7.1 %
Average	0.965	3.5 %	0.917	8.3 %

Table 3

Results of Quantization data (a, b) coding

	Pure DPCM entropy		DPCM entropy with Peano Scan	
	(a, b) bit rate	bit reduce %	(a, b) bit rate	bit reduce %
Lena	5.946+6.082=12.028	24.8 %	5.575+5.704=11.279	29.5 %
Lenna	5.805+5.907=11.712	26.8 %	5.416+5.509=10.925	31.7 %
Airplane	5.466+5.171=10.637	33.5 %	5.425+5.088=10.513	34.3 %
Pepper	5.788+5.840=11.628	27.3 %	5.654+5.707=11.361	29.0 %
Baboo	6.456+6.480=12.936	19.1 %	6.436+6.471=12.907	19.3 %
Average	11.788	26.3 %	11.397	28.8 %

Table 4

Results of Byte-oriented Map and Peano Scanned (a, b) coded by Arithmetic Coding

	Proposed method			AMBTC bit rate
	Bit-Map	Quantization data (a, b)	Bit-rate	
Lena	0.923	5.721+5.843=11.564	1.646	2.000
Lenna	0.901	5.562+5.652=11.214	1.602	2.000
Airplane	0.902	5.771+5.446=11.217	1.614	2.000
Pepper	0.954	5.800+5.845=11.645	1.682	2.000
Baboo	0.937	6.565=6.600=13.165	1.756	2.000
Average	0.923	11.761	1.660	2.000