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AMBTC Based Adaptive Compression Using Ordered and Interpolated Intensity Values

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ABSTRACT: In this paper Color image data compression using absolute moment block truncation coding scheme (AMBTC) is implemented. This compression technique reduces the computational complexity and achieves the optimum minimum mean square error and PSNR. It is an improvised version of BTC, obtained by preserving absolute moments. AMBTC is an encoding technique that preserves the spatial details of digital images while achieving a reasonable compression ratio. The simulation results obtained indicate that both the computational complexity of and the reconstructed image quality obtained using AMBTC algorithm are better than those obtainable with other existing BTC algorithms.

KEYWORDS: Image compression; Shade block, Medium block, Edge detailed block interpolation; bpp; PSNR; MSE;

I. INTRODUCTION

Generally images take up more storage space and take more time to get transmit across network. Image compression method is used to reduce the cost of storing, retrieving and transmission of images across a network [1]. One of the primary goals of image compression is to reduce the size of data wanted to represent the image while maintain the essential information [2]. There are two type of Image compression technique: lossless techniques and lossy technique. A lossy compression technique provides much higher compression ratio than lossless method. The presentation of any compression technique is calculated in terms of 1.Compression ratio 2.Signal-to-Noise Ratio (quality of the reconstruct image) and 3.Encoding and Decoding Speed [3]. In lossy image compression technique, the unnecessary information can be compressed [4]. One such lossy image compression method is Block Truncation coding (BTC) method. BTC is one of the recent techniques used to compress image data. The computational difficulty is lee in terms of BTC when compared to other technique. A compression rate of 2 bpp is achieved by BTC [5] & [6]. The compressed image is only an estimate of the original image. While some data is removed, for person Visual System, there is no a great deal difference between the original and the compressed image. In encoding procedure, for each input image block of size 4x4 pixels, a bit plane is shaped by replacing each pixel value with either 1 or 0. When the pixel value is greater than mean, it is coded as 1, or else 0. Two algebraic moments of size 16 bits are preserved along with the bit plane [7].

The bit-rate achieved with BTC can further be condensed by reducing the amount of data wanted to represent the Bit plane by dropping few bits. . The dropped bits can be generated at the decoding phase by means of the Interpolation technique [8]. By utilizing interpolation technique, the size of bit plane is decreased from 16 bits to only 8 bits prompting a bit rate of 1.75 bpp diminished from 2 bpp. The complete number of bits is 24 for each blocks and the bit rate is decreased from 2 to 1.5 bits/pixel. In BTC, the factual overheads: the standard Mean and standard deviation are saved for each info square. The shortened blocks of the BTC is the one-piece yield of the quantizer for each pixel in the blocks.

A basic variation of BTC called Absolute Moment Block Truncation Coding (AMBTC) was introduced by Lema and Mitchell, and it saves the higher mean and lower mean of the blocks [9]. The interpolative strategies are utilized to code

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the compressed bit plane of BTC [10, 11]. An algorithm for preserving moments which outcome in less mean square error (MSE) was prospect in [12]. To reduce the bit rate additional, few adaptive Block Truncation Coding techniques have been evolved: A four level four level quantizer has been designed in [13] and an idea of Multilevel Quantizer has been proposed in [14]. The variation between the original image and the reconstructed image is called Mean Square Error (MSE) and is calculated by the Eq. (1). The Quality of the reconstructed image is calculated using Peak Signal to Noise Ratio (PSNR) and is computed using the Eq. (2). PSNR is the inverse of MSE.

II. STANDARD BTC

In BTC Algorithm, the image is divided in to non-overlapping blocks of size 4 x 4 pixels. The mean \bar{x} is computed using for each block. Block Truncation Coding (BTC) works by dividing the image into small sub blocks of size 4x4 pixels and then reducing the number of gray levels within each block. This reduction is performed by a quantizer that adapts to the local image statistics. The basic form of BTC divides the whole image into N blocks and codes each block using a two-level quantizer. The two levels, \mathbf{a} and \mathbf{b} are computed using the mean (\bar{x}) and standard deviation (σ) of the gray levels within the block and are preserved. Each pixel value within the block is then compared with the mean and then is assigned to one of the two levels [19].

The \bar{x} and σ are calculated using the equations (2, 1) and (2, 2)

$$\bar{x} = 1/m \sum_{i=1}^m x_i \quad (2.1)$$

$$\sigma = \sqrt{\sum (x - x_i)^2 / m} \quad (2.2)$$

Where, m is the number of pixels in the each block, X_i is the original value of the block. If the pixel value of the each block is greater than or equal to mean, it is represented by '1' and if less than the mean, it is presented by '0'. The collection of '1s or 0's for each block is called a bit plane \mathbf{B} . in BTC, two statistical moments \mathbf{a} and \mathbf{b} are computed using the equations (2,3) and (2,4) and are preserved along with the bit plane for reconstructing the image. The compressed image is transmitted or stored as a set $\{\mathbf{B}, \mathbf{a}, \mathbf{b}\}$

$$\mathbf{a} = \bar{x} - \sigma \sqrt{\frac{q}{m-q}} \quad (2.3)$$

$$\mathbf{b} = \bar{x} + \sigma \sqrt{\frac{q}{m-q}} \quad (2.4)$$

where, q is the number of pixel values greater than or equal to \bar{x} and $m-q$ is the number of pixels whose gray levels are less than \bar{x} . While reconstructing the image, the $\mathbf{0}$ in the bit plane is replaced by \mathbf{a} and the $\mathbf{1}$ in the bit plane is replaced by \mathbf{b} . The difference between the original image and reconstructed image is called Mean Square Error (MSE) and is calculated using the equation (2.5). The quality of the reconstructed image is called the Peak Signal to Noise Ratio (PSNR) is calculated using the equation (2.6) and is the inverse of MSE.

$$MSE = \frac{1}{N} \sum_{i=1}^N (y_i - x_i)^2 \quad (2.5) \quad PSNR = 10 \cdot \log_{10} (255^2 / MSE) \quad (2.6)$$

2.1 Absolute Moment Block Truncation Coding (AMBTC)

AMBTC is the variant of BTC and introduced by lema and Mitchell [29]. In this method, two statistical moments \mathbf{a} (lower mean) and \mathbf{b} (higher mean) calculated using using the equations, (2.7) and (2.8) are preserved along with

the bit plane. $\bar{x}_l = \frac{1}{m-q} \sum_{x_i < \bar{x}} x_i$ (2.7) $\bar{x}_h = \frac{1}{q} \sum_{x_i > \bar{x}} x_i$ (2.8)

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The coding and decoding processes are very fast for AMBTC because the square root calculation and multiplications are omitted.

III. PROPOSED METHOD

The proposed method is based on Adaptive Block Transaction Coding using ordered block and interpolation is used for reducing bit rate and to improve the image quality. The input image is divided into blocks of size 4 x 4. All the input image blocks are categorized into three groups, based on the magnitude m values, where m is calculated using the equation (3.1).

$$MD = \sum_{i=1}^{16} abs(x_i - \text{mean})$$

The blocks are categorized into three groups as follows:

If $m < TH1$, then it is a Shade block
Else if $m < TH2$, it is a Medium block
else, it is an Edge block.

If m is less than or equal to threshold value (TH1), the block is classified as Shade block. If m lies between Th1 and Th2, the blocks are categorized as Medium blocks. In case of a Medium block, the pixel values in the block are sorted and divided into two clusters. The sorted block SB will be as given in the equation (3.2).

$$SB = \{p_i, p_{i+1}, p_{i+2}, \dots, p_{i+15}\} \text{ where } p_i < p_{i+n} \text{ and } 1 \leq n \leq 15 \tag{3.2}$$

The average values (Q1 and Q2) of both the clusters are computed using the equations (3.3) and (3.4).

$$Q1 = (p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8) / 8 \tag{3.3}$$

$$Q2 = (p_9 + p_{10} + p_{11} + p_{12} + p_{13} + p_{14} + p_{15} + p_{16}) / 8 \tag{3.4}$$

The bit plane is generated using mean value. If the original pixel value is $<$ mean, then it is coded as 0, else it is coded as 1. Consider the input image block given below: If the magnitude m is greater than TH2, the block is categorized into high detailed edge block. In high detailed edge block, the original image block is ordered as given in equation (3.5) and divided into four clusters. For each cluster, the average pixel value is computed using the equations (3.6, 3.7, 3.8 and 3.9). These average values form the four quantizers namely Q1, Q2, Q3 and Q4.

$$SB = \{p_i, p_{i+1}, p_{i+2}, \dots, p_{i+15}\} \text{ where } p_i < p_{i+n} \text{ and } 1 \leq n \leq 16 \tag{3.5}$$

The average values (Q1, Q2, Q3 and Q4) of both the clusters are computed using the equations (3.6), (3.7) and (3.8), (3.9)

$$Q1 = (p_1 + p_2 + p_3 + p_4) / 4 \tag{3.6}$$

$$Q2 = (p_5 + p_6 + p_7 + p_8) / 4 \tag{3.7}$$

$$Q3 = (p_9 + p_{10} + p_{11} + p_{12}) / 4 \tag{3.8}$$

$$Q4 = (p_{13} + p_{14} + p_{15} + p_{16}) / 4 \tag{3.9}$$

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For example, if the following is the input block,

$$\begin{pmatrix} 128 & 70 & 47 & 27 \\ 128 & 76 & 47 & 27 \\ 128 & 76 & 41 & 27 \\ 128 & 76 & 47 & 29 \end{pmatrix}$$

As explained above, the input image block is sorted and the sorted block is given below:

$$SB = \{27,27,27,29,41,47,47,47,70,76,76,76,128,128,128,128\}$$

The sorted values are divided into four different equal sets and the average of all the four clusters are computed as:

The average of the first cluster is $27.5 \rightarrow 28(Q1)$

The average of the second cluster is $45.5 \rightarrow 46(Q2)$

The average of the second cluster is $74.5 \rightarrow 75(Q3)$

The average of the second cluster is $128 \rightarrow 128(Q4)$

Now the input image block is transformed into the following Bit-plane and four Quantizers Q1, Q2, Q3 and Q4.

$$\begin{pmatrix} 11 & 10 & 01 & 00 \\ 11 & 10 & 01 & 00 \\ 11 & 10 & 01 & 00 \\ 11 & 10 & 01 & 00 \end{pmatrix}$$

The size of the input image block is $16 \times 8 \rightarrow 128$ bits. But after transformation, the size has been reduced to $32 + 8 + 8 + 8 + 8 \rightarrow 64$ bits, thus leading to compression. The same block after storage or transmission, it is regenerated as follows:

All the 00's in the bit plane are coded as Q1, the 01's are coded as Q2, the 10's are coded as Q3 and 11's are coded as Q4. Now the reconstructed image block will be

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128	75	46	28
128	75	46	28
128	75	46	28
128	75	46	28

Figure 3.2 32 Bits –Bitmap

Step 01: Split the input image into blocks of size 4 x 4 blocks.

Step 02: For each 4 x 4 block, perform the following.

Step 03: Categorize the blocks as Shade, Medium and Edge blocks, based on magnitude m using the equation (3.1).

Step 04: If it is shade block, preserve the mean of the block and go to step 2.

Step 05: If medium edge block, compute the 2-level quantizer using the equations (3.3) & (3.4).

Step 06: Generate the 16 bit plane based on 2-level quantizer

Step 07: Apply interpolative method to reduce the bit plane and go to step2.

Step 08: If it is high detailed edge block, compute the 4-level quantizer using the equation

Step 09: Generate the 32 bit plane based or 4-level quantizer

Step 10: Apply interpolative method to reduce the bit plane and go to step2.

Step 11: In decoding stage, all quantizer are multiplied by 4.

Second level of compression

The size of Bit-plane is generated using ordered BTC and is further reduced using interpolative method. In this interpolative method, 16 components of the bit-plane are reduced to 8 components. The boldfaced components as in figure 2.7 are dropped off and hence the size of bit-plane is 8 bits rather the 16 bits.

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X ₁₁	X ₁₂	X ₁₃	X ₁₄
X ₂₁	X ₂₂	X ₂₃	X ₂₄
X ₃₁	X ₃₂	X ₃₃	X ₃₄
X ₄₁	X ₄₂	X ₄₃	X ₄₄

Figure 3.4: pattern of dropping bits in interpolation technique.

In decoding phase, the pixel values with respect to the dropped bits are recovered by taking the arithmetic mean of the adjacent pixel values using the equations (3.10, 3.11, 3.12, 3.13, 3.14, 3.15 and 3.16)

$$x_{ij} = \frac{1}{3}(x_{i,j-1} + x_{i+1,j} + x_{i,j+1}) \quad \text{for } i=1 \text{ and } j=2 \quad x_{ij} = \frac{1}{2}(x_{i,j-1} + x_{i+1,j}) \quad \text{for } i=1 \text{ and } j=4$$

$$x_{ij} = \frac{1}{3}(x_{i-1,j} + x_{i,j+1} + x_{i+1,j}) \quad \text{for } 2 \text{ and } j=1$$

$$x_{ij} = \frac{1}{4}(x_{i-1,j} + x_{i,j-1} + x_{i,j+1} + x_{i+1,j}) \quad \text{for } i=2 \text{ (or) } 3 \text{ and } j=3 \text{ (or) } 2$$

$$x_{ij} = \frac{1}{3}(x_{i-j,j} + x_{i,j-1} + x_{i+1,j}) \quad \text{for } i=3 \text{ and } j=4 \quad x_{ij} = \frac{1}{2}(x_{i-1,j} + x_{i,j+1}) \quad \text{for } i=4 \text{ and } j=1$$

(3.15)

$$x_{ij} = \frac{1}{3}(x_{i-1,j} + x_{i,j-1} + x_{i,j+1}) \quad \text{for } i=4 \quad j=3$$

Third level of compression

The quantizes of both Medium and Edge blocks are further divided by 4 to reduce the number of bits required to represent them. Thus the number of bits is reduced from 8 to 6.

Reconstruction of Images

The first step in reconstructing the image is to multiply the quantizes by 4 to get back the approximate values. In case of a Shade block, the output block is reconstructed by filling it with the Mean Value for all the pixels. For a Medium Detail block, the 1s in the respective Biplane are replaced with Q2 and the 0s are replaced with Q1. For an Edge block, the 00s are replaced with Q1, 01s are replaced with Q2, 10s are replaced with Q3 and 11s are replaced with Q4.

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PSNR and bpp are the metrics used to measure the performance of the compression technique with respect to quality of the reconstructed image and the compression rate.

IV. RESULTS AND DISCUSSION

4. Experimental Results and Discussions

All experiments are performed with the benchmark gray scale images of size 512 x 512. The input images are Airplane, Lena, Boats, Sailboat, Zelda, Girl, Toys and Gold hill. The images taken for the study are given in Figure 4.1 and the algorithms are implemented using MATLAB R2017a. The Hardware used is, the Intel® Pentium® core™ i3-2.00GHZ 1.90GHZ with 64 bit Windows operating system with 4GB RAM.



Figure 4.1: Input Images taken for Study

Quality Measurement

The Peak Signal-to-Noise Ratio (PSNR) is used to measure the image quality. PSNR is defined as:

$$PSNR = 10 \log_{10} \left[\frac{255^2}{MSE} \right] \quad (4.1)$$

Where, MSE is the Mean Square Error between the original image and compressed image. MSE is defined as:

$$MSE = \frac{1}{M \times N} \sum_{i=1}^M \sum_{j=1}^N (I(i, j) - I'(i, j))^2 \quad (4.2)$$

Where, M is number of rows and N is number of columns. $I(i, j)$ and $I'(i, j)$ denote the pixel values of Original image and Compressed-image respectively.

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The bitrate is used to analyze the coding efficiency of any Compression algorithm. The bitrate is computed using the equation (4.3), where C represents the length of compression code, $M \times N$ is the size of the original image. The bitrate measured is represented in terms of bits per pixel (bpp). The lower the bitrate, higher the coding efficiency is.

$$bitrate = \frac{C}{M \times N} (bpp) \quad (4.3)$$

Images	Existing Methods								Proposed Method	
	AMBTC		ABTC		IABTC		AD_AMBTC TH=25		TH3(100-300)	
	PSNR	BPP	PSNR	BPP	PSNR	BPP	PSNR	BPP	PSNR	BPP
Lena	37.87	2.00	36.28	0.91	37.52	0.82	35.94	0.88	35.28	0.60
Airplane	37.54	2.00	36.78	1.06	38.22	0.88	36.86	1.00	35.63	0.63
Boat	36.07	2.00	34.66	1.16	36.18	1.07	34.49	1.03	33.61	0.65
Girl	38.73	2.00	37.31	0.83	38.36	0.72	36.95	0.83	36.27	0.58
Pepper	38.15	2.00	36.29	0.89	37.41	0.78	36.04	0.86	35.40	0.59
Sail Boat	35.20	2.00	34.29	1.31	35.56	1.12	34.44	1.16	33.34	0.69
Toys	38.37	2.00	37.52	0.97	38.68	0.80	37.47	0.95	35.99	0.63
Gold hill	37.39	2.00	35.41	0.95	36.79	0.96	34.80	0.89	34.22	0.61
Average	37.41	2.00	36.07	1.01	37.09	0.89	36.12	0.95	34.96	0.62

Table 4.1: Comparison of PSNR and BPP of Proposed method with Various Threshold (TH1, TH2 and TH3)

It is observed from the Table 4.1, that the results generated with the threshold values of 100 and 300 as Th1 and Th2 are better when compared to that of other threshold values. Hence these two threshold values are fixed as best values for the better performance of the proposed compression technique as the bpp achieved is **0.58**.

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Images	Proposed Method					
	Threshold (TH1=50,TH2=150)		Threshold (TH1=100,TH2=200)		Threshold (TH1=100,TH2=300)	
	PSNR	BPP	PSNR	BPP	PSNR	BPP
Lena	36.66	0.80	34.45	0.64	35.28	0.60
Airplane	37.15	0.87	36.01	0.73	35.63	0.63
Boat	35.12	0.97	33.90	0.74	33.61	0.65
Girl	37.56	0.73	36.45	0.61	36.27	0.58
Pepper	36.49	0.78	35.57	0.65	35.40	0.59
SailBoat	34.38	1.03	33.65	0.81	33.34	0.69
Toys	37.28	0.81	36.30	0.69	35.99	0.63
Goldhill	35.86	0.87	34.32	0.64	34.22	0.61
Average	36.31	0.85	35.08	0.68	35.96	0.58

Table 4.2: Comparison of PSNR and BPP of Proposed and Existing method with Various Threshold (TH1, TH2 and TH3)

From Table 4.2, it is observed that the proposed technique outperforms the existing methods AMBTC, ABTC, IABTC and AD-AMBTC in terms of bpp without much loss in quality (PSNR) of the reconstructed images.

V. CONCLUSION

The proposed method is a BTC based technique for enhancing the quality of reconstructed image and to improve the coding efficiency. It is an adaptive and interpolative scheme, based on AMBTC. In the proposed method, the blocks are categorized into shade, medium and edge blocks. In the shade blocks, bit plane is omitted and the mean value only stored. In medium blocks, 2-quantizer and 16-bit plane are generated using ordered BTC technique. Bit plane is reduced by interpolative method. In edge blocks 4-quantizer and 32 bit plane are generated using ordered BTC technique and bit plane is reduced using interpolative method. All the quantizers are divided by 4 to reduce the bitrate. Existing BTC, AMBTC, ABTC, IABTC and AD-AMBTC are taken for the study and the result obtained with these techniques are compared against the proposed method. In all the cases, the proposed method outperforms the existing methods that are discussed in this thesis, with respect to bpp and PSNR. The average bpp obtained with existing techniques are 2, 0.98, 0.87 and 0.92. The proposed method gives an average of bpp are 0.84, 0.67 and 0.61 for various threshold values. The proposed method yields a good PSNR value, when compared to that of the existing techniques. It is easy to implement this technique and also efficient results are obtained. This technique can be extended for color images and in future, these techniques can also be applied for video compression.

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