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Adaptive AMBTC using Bit Plane Patterns for Compressing Still Images

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***Abstract*—** Block Truncation coding is a simple and efficient technique for compressing still images. Absolute Moment Block Truncation Coding (AMBTC), an improved form of BTC has been enhanced in this proposed method to achieve better results in terms of PSNR (Peak Signal to Noise Ratio) and bpp (bits per pixel). In BTC and AMBTC based techniques, only two quantizers are used. In the proposed method, four quantizers are used for improving the quality of reconstructed images, by categorizing the blocks based on the distribution of gray levels among the pixels. Adaptive bit-plane patterns are generated to improve the coding efficiency. This method is tested with standard benchmark images such as Lena, Cameraman, Boats, Bridge, Baboon and Kush. For all the images, the proposed method gives better results in terms of bpp and PSNR when compared to that of existing techniques.

***Keywords*—** AMBTC, bpp, Coding Efficiency, hMean, Image Compression, lMean, PSNR.

I. INTRODUCTION

Data compression is the mapping of a data set from one form to another form to decrease the number of bits required to represent the data. Transmission of images has become inevitable now-a-days and data required for storing or transmitting images is in huge volumes. To reduce the cost associated with Image storage and transmission, image compression techniques are essential in today's scenario. Image compression finds its applications in various fields such as Video Conferencing, Video Phones, TV Transmission [1]. The image compression techniques are accepted only if the quality of image is retained to a certain extent with the reduction in data [2]. Image compression techniques are of two types: 1. Lossless and 2. Lossy techniques. In Lossless compression, reconstructed image is exactly the same as that of the original image while in lossy compression, some data is lost and the reproduced image is only an approximation of the original image.

Compression is done in two ways: Spatial domain and Transform domain. Discrete Cosine Transform(DCT) and Discrete Wavelet Transform(DWT) are the compression techniques based on the Transform Domain. Block Truncation Coding (BTC) and Vector Quantization (VQ) are based on Spatial Domain. BTC was first proposed by Delp and Mitchell in 1979 [3]. It is a lossy image compression technique which uses moment preserving quantization method for compressing digital gray scale images. It is used in real-time image transmission due to its simplicity, performance and superior channel resisting capability [4]. In its simplest form, the objective of BTC is to preserve the sample mean and sample standard deviation of a gray scale image [5].

BTC has the advantage of providing good image quality of the compressed images and the image encoding/decoding procedures of BTC are very simple. BTC takes low computational cost and is suitable for real time multimedia applications [6]. The bit rate of the BTC is high when compared to that of other compression techniques such as JPEG [7] or JPEG 2000 [8]. Many modified BTC techniques have been proposed to further reduce the bit rate and improve the quality of the image. Somasundaram and Vimala developed an efficient BTC by exploiting the feature of inter-pixel correlation [9]. Pasi Franti et al. [10] introduced the various improvements of basic BTC. Lucas Hui has proposed Adaptive BTC to classify the image blocks as Edge and Shade blocks to improve the quality with variable bit rate [11]. Vimala et al. [12] have proposed IABTC which is an improved form of ABTC where the bitrate is reduced from 2 *bpp* to 1 *bpp*.

In this paper, we proposed a method based on Absolute Moment Block Truncation Coding (AMBTC) with low computational complexity. Proposed method includes bit plane omission for few blocks. A Bit Plane Block (BPB) with 32 adaptive visual patterns is generated for efficient coding. From the simulated results, we found that the proposed method gives better performance in terms of image quality and bitrate. A review of the BTC and AMBTC methods is given in section II. The proposed method is explained in section III. Results are discussed in section IV and the conclusion is given in section V.

II. RELATED WORK

A. Block Truncation Coding (BTC)

In BTC, the input image is divided into non-overlapping blocks of *n x n* pixels, typically *4 x 4*. Each image block is compressed using two quantization levels and one bitmap. For each block, the mean $(\bar{x})$ and standard deviation (σ) are derived from (1) to (3).

$$m_1 = \bar{x} = \frac{1}{k}\sum_{i=1}^{k} x_i \quad (1)$$

$$m_2 = \frac{1}{k}\sum_{i=1}^{k} x_i^2 \quad (2)$$

$$\sigma = m_2 - m_1^2 \quad (3)$$

Where ***k*** is the number of pixel values in a block and x_i is the ***i^th^*** pixel value of the block. The bit-plane (*BP*) is calculated using (4).

$$BP = \begin{cases} 1 & \text{if } x_i \geq \bar{x} \\ 0 & \text{otherwise} \end{cases} \quad \text{for } i = 1,2,...,k \quad (4)$$

The two level quantizers Q_1 and Q_2 are derived from (5) & (6).

$$Q_1 = m_1 - \sigma\sqrt{\frac{q}{k-q}} \quad (5)$$

where ***q*** is number of pixels of a block whose pixel value is greater than or equal to the Mean of the block and ***k*** is the number of pixels in a block.

$$Q_2 = m_1 + \sigma\sqrt{\frac{k-q}{q}} \quad (6)$$

The reconstructed block *(RB)* is calculated for the corresponding bit-plane*(BP)*from (7).

$$RB = \begin{cases} Q_1 & \text{if } BP_i = 0 \\ Q_2 & \text{if } BP_i = 1 \end{cases} \quad \text{for } i = 1,2,...,k \quad (7)$$

The bpp achieved with BTC is 2.

The difference between the Original image and reconstructed image is called as Mean Square Error (MSE) is calculated from (8). The quality of the reconstructed image called as Peak Signal to Noise Ratio (PSNR) is calculated from (9).

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(y_i - x_i)^2 \quad (8)$$

$$PSNR = 10\log_{10}\left[\frac{255^2}{MSE}\right] \quad (9)$$

B. Absolute Moment Block Truncation Coding (AMBTC)

Lema and Mitchell [13] developed a simple and fast variant of BTC, named Absolute Block Truncation Coding (AMBTC). In AMBTC, an image is divided into non-overlapping blocks of size *4 x 4*pixels. Calculate the mean value of the block using (1). Pixels in the image blocks are classified into two ranges of values. The upper range of values are greater than or equal to mean $(\bar{x})$ value and the remaining values fall in lower range. The Quantizers of AMBTC, the *hMean* and *lMean* are calculated using (10) and (11).

$$hMean = \frac{1}{k}\sum_{x_i \geq \bar{x}}^{n} x_i \quad (10)$$

$$lMean = \frac{1}{16-k}\sum_{x_i < \bar{x}}^{n} x_i \quad (11)$$

Where ***k*** is the number of pixels whose pixel value is greater than the mean $(\bar{x})$. The bit plane BP is generated using the (4). In the decoding phase, image block is reconstructed by replacing the 1's with *hMean* and 0's with *lMean* which improves the quality of the reconstructed image. AMBTC requires less computation than BTC [14].

C. Minimum Mean Square Error (MMSE)

MMSE is the iterative process of AMBTC and is used to reduce the Mean Square Error. In MMSE, the given input image is divided into non overlapping blocks of size *4x4* pixels. The quantizers ***a*** and ***b*** are initialized with $min(x_i)$ and $max(x_i)$ respectively and the threshold value ***t*** is computed using (12). To improvise the values of ***a*** and ***b***, the equations (13) and (14) for computing a' and b' are repeated until ***a'*** and ***b'*** become equal to ***a*** and ***b*** respectively.

$$t = (a+b)/2 \quad (12)$$

$$a' = \frac{1}{(k-q)}\sum_{x_i < t} x_i \quad (13)$$

$$b' = \frac{1}{q}\sum_{x_i \geq t} x_i \quad (14)$$

Where ***q*** is the number of pixels whose intensity values are greater than or equal to the threshold value ***t*** and, ***k*** is the total number of pixels in each block.

D. Adaptive Block Truncation Coding (ABTC)

In ABTC, the input blocks are classified into three groups namely

1. Low activity Blocks
2. Medium activity Blocks
3. High activity Blocks

Only the Mean value is stored for low activity blocks. Normal BTC is applied for medium activity blocks. For each block a bit-plane and two quantizers are stored. A 4-level quantizer is applied for high activity blocks and the quantizers are computed using (15).

$$\left.\begin{aligned} a &= X_{min} \\ b &= (2X_{min} + X_{max})/3 \\ c &= (X_{min} + 2X_{max})/3 \\ d &= X_{max} \end{aligned}\right\} \quad (15)$$

Use same iterative process to optimize the threshold values t_1,t_2 and t_3 for categorizing the input blocks into low, medium and high activity blocks.

III. Proposed Method

In this method, the input image is divided into blocks of size 4 x 4 pixels, where 4 x 4 is the optimal size of block which maintains a trade-off between the quality of the reconstructed image and better compression ratio. The input image blocks are categorized into low-detailed block and high-detailed block based on the magnitude value ***D*** using (16).

$$D = \sum_{i=1}^{16} |Mean - x_i| \quad (16)$$

Where x_i represents i^{th} pixel value in the block. For a low-detailed block, only the Mean value is stored. For high-detailed blocks, two quantizers *hMean* and *lMean* are computed using (10) and (11) based on AMBTC.

The coding efficiency is further improved by identifying the duplicate occurrences of bit-planes. The bit-planes are sorted in descending order based on the number of occurrences. A Bit-Plane Block (BPB) holding the bit-planes having duplicate occurrences is generated. For a block having bit-plane in BPB, the respective index is stored, else the corresponding bit-plane of is stored. For both the cases, the two quantizer values (hMean and lMean) divided by 4 are stored. This leads to further compression by 4 bits per block.

A. Encoding Steps

Step 01: Divide the given image into non-overlapping blocks of size of *4 x 4* pixels.
Step 02: For each block, perform the following steps.
Step 03: Compute the block *Mean* and magnitude *D*.
Step 04: Categorize the blocks in to low-detailed and high-detailed blocks.
Step 05: If low-detailed block, store the Mean and go to Step 12.
Step 06: For high-detailed blocks, follow the steps from 7 to 8
Step 07: Calculate *hMean* and *lMean* based on (10) and (11) and store.
Step 08: Construct the bit-plane BP for each block.
Step 09: Generate BPB with bit planes having duplicate occurrences.
Step 10: For a block having unique bit-plane, store the actual bit-plane.
Step 11: For a block having bit plane as part of BPB, store the index of the corresponding Bit plane in BPB.
Step 12: Store either the i) Mean or ii) BPB index / Bit plane along with two quantizers, depending on the nature of the input block.

While decoding the image, the pixel values of low detailed blocks are generated using the respective Mean values. For a high detailed block having index of bit plane in BPB, the corresponding bitplane is taken and the pixel values are deflated using the *hMean* and *lMean* based on 1 and 0s.

IV. Results and Discussion

Bench mark images such as Lena, Cameraman, Boats, Bridge, Baboon and Kush are tested with the proposed method using Matlab R2014b version. BTC and AMBTC give 2 bpp for storing the images. The proposed method is an adaptive version of AMBTC, where the bitrate changes depending on the nature of the gray level distribution and yields an average of 1.02 bits per pixel (bpp), which is a significant improvement. The simulated results of the proposed method in terms of bpp and PSNR are compared against the results obtained with the existing techniques such as BTC, AMBTC, MMSE and ABTC. Of these four techniques, ABTC is an adaptive version. In all the cases, the results of the proposed method are better. The bpp obtained with BTC, AMBTC, MMSE is 2 bpp. Though ABTC is an adaptive technique, the average bpp obtained is also 2 bpp. But the average bpp obtained with the proposed method is 1.02. A minimum bpp of value 0.88 is obtained for Lena image and a maximum bpp value of 1.48 is achieved for Bridge image.

The PSNR values (quality of reconstructed images) are comparatively better than that of the existing methods. The average PSNR values 33.78, 34.01, 34.53 and 33.20 are obtained with the techniques BTC, AMBTC, MMSE and ABTC. But the proposed method gives an average PSNR value of 35.46, which is a significant improvement. This method is simple and easy to implement and the results obtained with this method are also good in terms of *bpp* and *PSNR* values.

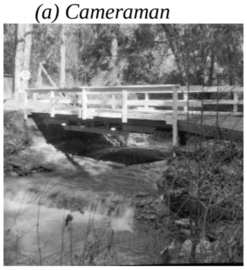
The input images taken for the study are given in Fig. 1. The reconstructed images by all the methods are given in Fig. 2 for visual comparison. As far as JPEG is concerned, [15] the quality (PSNR) of reconstructed image is only 27.02, but with the proposed method, we achieve an average PSNR of value 35.46. This is a very good improvement.

Table 1- Comparison of results in terms of BPP and PSNR with respect to BTC, AMBTC, MMSE, ABTC and Proposed Methods.

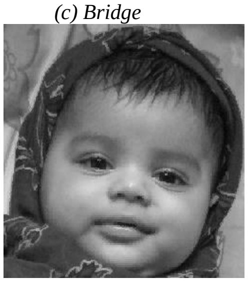
Image	BTC		AMBTC		MMSE		ABTC		Proposed Method	
	BPP	**PSNR**	**BPP**	**PSNR**	**BPP**	**PSNR**	**BPP**	**PSNR**	**BPP**	**PSNR**
Cameraman	2	32.07	2	32.13	2	32.70	1.90	30.19	**0.92**	**35.93**
Baboon	2	37.14	2	37.46	2	37.68	2.13	37.57	**0.91**	36.40
Boats	2	32.77	2	33.15	2	33.81	1.82	30.36	**1.04**	**35.32**
Bridge	2	30.68	2	30.94	2	31.47	2.09	31.00	**1.48**	**32.99**
Lena	2	34.62	2	34.85	2	35.39	2.18	35.60	**0.88**	**36.14**
Kush	2	35.41	2	35.55	2	36.11	1.88	34.50	**0.92**	**35.99**
Average	**2**	**33.78**	**2**	**34.01**	**2**	**34.53**	**2.00**	**33.20**	**1.02**	**35.46**


(a) Cameraman


(b) Boats


(c) Bridge


(d) Lena


(e) Kush

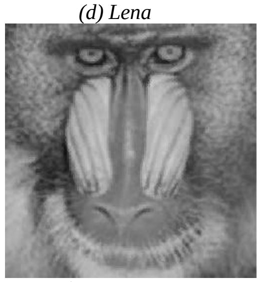

(f) Baboon

Figure 1. Input Images


(a)Original


(b) BTC
PSNR:34.62, Bpp:2


(c) AMBTC
PSNR:34.85
Bpp:2


(d) MMSE
PSNR: 35.39
Bpp: 2


(e) ABTC
PSNR:35.60
Bpp:2.18


(f) Proposed
PSNR: 36.14
Bpp: 0.88

Figure 2. (a) Original Image, (b)-(f) Reconstructed Images of BTC, AMBTC, MMSE, ABTC and the Proposed (AAMBTC) methods.

V. CONCLUSION

The proposed method is an improved and adaptive version of Absolute Moment Block Truncation Coding. Bit-plane patterns are generated for duplicate blocks to improve the coding efficiency. Existing BTC and AMBTC based techniques such as BTC, AMBTC, MMSE and ABTC are taken for the study and the results obtained with these techniques are compared against the proposed method. In all the cases, the proposed method outperforms all the aforementioned techniques in this paper, with respect to bpp and PSNR. The average bpp obtained with these techniques is 2 and the proposed method gives an average bpp of 1.02. 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 is also applicable for color images and in future, this technique may be applied for Video Compression.

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