Performance Evaluation of Block Truncation Coding for Image Compression

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ABSTRACT
This paper addresses the area of image compression as it is applicable to various fields of image processing. On the basis of evaluating and analyzing the current image compression techniques this paper presents Parallel Implementation of Block Truncation Coding (BTC) for Image Compression. It also includes various benefits of using image compression techniques.

Keywords
BTC, Compression Ratio, Compression Rate, Redundancy, lossless and Lossy.

1. INTRODUCTION
The digital techniques for image coding are having a very fast increasing development in this data transmission era. Image compression and data compression in general have been an important research area for information technology industry. Large amounts of memory space as well as wide channel bandwidth are needed to save or transmit an image. In fact these are the most important problems facing the information technology today; space and speed. Therefore it is imperative to reduce the number of necessary bits to encode an image.

Advanced in computer technology for mass storage and digital processing have paved the way for implementing advanced data compression techniques to improve the efficiency of computation, transmission and storage of images. This requires an appropriate model for image compression based on the characteristics and the statistical properties of the image. Coding in the spatial domain involves the direct manipulation of the sample image data to remove existing redundancies. Spatial coding is usually simple to implement both in terms of memory requirement and number of operations [1-6].

The efficiency of a compression algorithm is measured by its data compression ability, the resulting distortion and as well by its implementation complexity. The complexity of data compression algorithms is a particularly important consideration in their hardware implementation. Image transmission applications are in broadcast television, remote sensing via satellite, aircraft, radar, sonar, teleconferencing, computer communication, facsimile transmission etc. Image storage is required most commonly for education, and business. [7-10]

The difference between the original image and the compressed image is called Mean Square Error (MSE) and is calculated using the equation (1).The quality of the reconstructed image called the Peak Signal to Noise Ratio (PSNR) is calculated using the equation (2) and is the inverse of MSE.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(yi - xi)_2 \qquad \text{..........(1)}$$

$$PNSR = 10\log(255^2/MSE) \qquad \text{............(2)}$$

computing equipment of that era. In the 1970s, digital image processing proliferated, when cheaper computers and dedicated hardware became such as television standards conversion. As general- purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and compute- intensive operation [2-3].

Image processing operation can be roughly divided into three categories, Image Compression, image Enhancement. Restoration and Measurement Extraction. Image compression is familiar to most people .It involves reducing the amount of memory needed to store a digital image [4].

1.1 FUNDAMENTALS OF DIGITAL IMAGE PROCESSING
The various steps required for any digital image processing applications are listed below:

Image grabbing or acquisition

Preprocessing Segmentation

Representation and feature extraction

Recognition and interpretation.

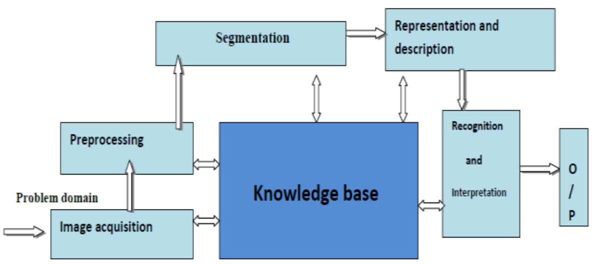

Fig.No.1.1: The fundamental steps in digital image processing.

The image compression techniques are broadly classified into two categories depending whether or not an exact replica of the original image could be reconstructed using the compressed image. These are:

- Lossless technique
- Lossy technique

1.2 LOSSLESS COMPRESSION TECHNIQUE

In lossless compression techniques, the original image can be perfectly recovered from the compressed (encoded) image. These are also called noiseless since they do not add noise to the signal (image).It is also known as entropy coding since it use statistics/decomposition techniques to eliminate/minimize redundancy. Lossless compression is used only for a few applications with stringent requirements such as medical imaging [7, 11].

Following techniques are included in lossless compression:

- Run length encoding
- Huffman encoding
- LZW coding
- Area coding

1.3 LOSSY COMPRESSION TECHNIQUE

Lossy schemes provide much higher compression ratios than lossless schemes. Lossy schemes are widely used since the quality of the reconstructed images is adequate for most applications .By this scheme, the decompressed image is not identical to the original image, but reasonably close to it [7, 11].

Major performance considerations of a lossy compression scheme include-

- Compression ratio
- Signal - to – noise ratio
- Speed of encoding & decoding.

Lossy compression techniques includes following schemes:

- Transformation coding
- Vector quantization
- Fractal coding
- Block Truncation Coding
- Subband coding

2. BTC FUNDAMENTAL

Block truncating coding (BTC) was introduced by Delp and Mitchell in 1979 [9]. In the BTC algorithm the input image is divided into non-overlapping block of size m× n pixels. Figure.1 shows the diagram of BTC for grayscale image compression[12].

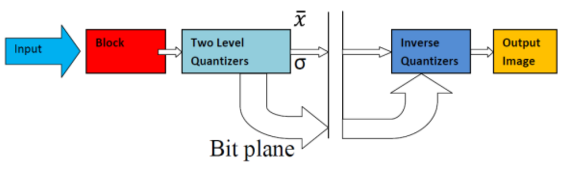

Fig. No. 2 : The original BTC system

The BTC algorithm involves the following steps:

a. The input image is divided into non-overlapping block of size m× n pixels.

b. For a two level (1 bit) quantizer select mean ($\bar{x}$) and Standard deviation (σ) values to represent each pixel in the block.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} xi \qquad \text{..........(3)}$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(xi - \bar{x})_2} \qquad \text{..........(4)}$$

Where xi represents the i[th] pixel value of the image block and n is the total number of pixels in that block.

c. The two values ($\bar{x}$) and σ are termed as quantizers of BTC. Taking as the threshold value a two level bit plane is obtained by comparing each pixel value xi with the threshold.

$$B = \begin{cases} 1, & xi \geq \bar{x} \\ 0, & x < \bar{x} \end{cases} \qquad \text{..........(5)}$$

Where B is a binary block used to represent the pixels.

d. Inverse quantizer of an image is reconstructed by replacing '1's in the bit plane with U and the '0's with L, which are given by:

$$U = \bar{x} + \sigma\sqrt{\frac{k}{y}}$$

$$L = \bar{x} - \sigma\sqrt{\frac{k}{y}} \qquad \text{..........(6)}$$

Where k and y are the number of 0's and 1's in the compressed bit plane respectively.

2.1 BTC Algorithm

The image (NxN pixels) is first divided into blocks of MxM pixels where M << N. Usually M is equal to 4 or 8. The digital representation of each pixel is truncated to one bit using thresholding as well as the preservation of some statistics of the block; usually the moments.[13]

Consider an image of dimension NxN. The image is subdivided into blocks of 4x4 pixels. The gray mean value of each block is computed first:

$$\bar{x} = \frac{1}{16}\sum_{i=1}^{16} xi \qquad \text{..........(7)}$$

Where 16 = (MxM) is the total number of pixels in a block. Then the gray value of each pixel is compared to the computed gray mean value $\bar{x}$:

If $x_i < \bar{x}$ then the pixel value is replaced by A.

If $x_i \geq \bar{x}$ then the pixel value is replaced by B.

In that way the whole block is replaced by a block of elements having values of A and B, which are coded by 0 or 1, respectively. This block of ones and zeros is called the "code table" which will be transmitted or stored. The values A and B are calculated such that the first moment and the second moment are preserved; they must be the same for both, the original and the reconstructed images. The first moment is the mean, given in equation (7) .The second moment is –

$$\overline{x^2} = \frac{1}{16}\sum_{i=1}^{16} xi_2 \qquad \text{……….(8)}$$

The first and the second moments in the reconstructed image are as follows:

First moment: $\frac{1}{m}[(m-q)A+qB]$ ……….(9)

Second moment: $\frac{1}{m}\;[(m-q)A^2+qB^2]$ ……..(10)

Where m is the total number of pixels in the block and q is the number of pixels with

$$x_i \geq \overline{x} \qquad \text{……(11)}$$

If the first and the second moments are to be preserved, we require that:

$$\overline{x} = \frac{1}{m}[(m-q)A+qB] \qquad \text{……(12)}$$

$$\overline{x^2} = \frac{1}{m}[(m-q)A^2+qB^2] \qquad \text{……(13)}$$

solving equation (12) and equation (13) , we have

$$A = \overline{x} - \sigma \sqrt{\frac{q}{m-q}} \qquad \text{……(14)}$$

$$B = \overline{x} + \sigma \sqrt{\frac{q}{m-q}} \qquad \text{……(15)}$$

where $\sigma = \sqrt{\overline{x^2} - (\overline{x})^2}$ is the standard deviation.

The information to be transmitted is therefore the code table for every block as well as the values of $\overline{x}$ and σ. At the receiving end, the block is reconstructed using the received data. The algorithm canbe summarize in figure 2.1.

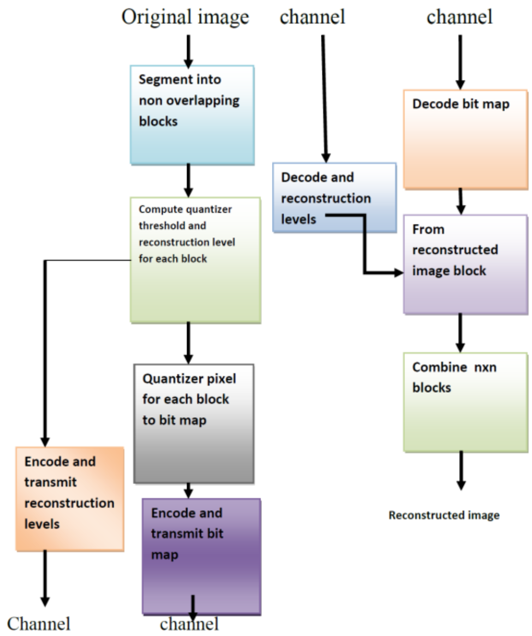

Fig. No. 2.1 Algorithms for encoding and decoding

ALGORITHM FOR THE PARALLELE BTC

Parallel Block Truncation Coding (PBTC) is a well-known compression scheme proposed in 1979 for the grayscale images. It was also called the moment-preserving block truncation [4]-[5] because it preserves the first and second moments of each image block. The PBTC algorithm involves the following steps: [12]

Step1 The input image is divided into non-overlapping block of size m× n pixels.

Step2 For a two level (1 bit) quantizer select mean ($\overline{x}$) and Standard deviation (σ) values to represent each pixel in the block.

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} xi$$

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(xi-\bar{x})_2}$$

Where xi represents the i^{th} pixel value of the image block and n is the total number of pixels in that block.

Step3 The two values ($\overline{x}$) and σ are termed as quantizers of BTC. Taking as the threshold value a two level bit plane is obtained by comparing each pixel value xi with the threshold.

$$B = \begin{cases} 1, & xi \geq \bar{x} \\ 0, & x < \bar{x} \end{cases}$$

Where B is a binary block used to represent the pixels.

Step4 Inverse quantizer of an image is reconstructed by replacing '1's in the bit plane with U and the '0's with L, which are given by:

$$U = \bar{x} + \sigma \sqrt{\frac{k}{y}}$$

$$L = \bar{x} - \sigma \sqrt{\frac{k}{y}}$$

Where k and y are the number of 0's and 1's in the compressed bit plane respectively.

3. RESULTS AND DISCUSSIONS

To verify the performance of the BTC and Parallel BTC, all the experiments were carried out with the standard images taken from open source viz. Saturn, Rice, Cameraman, Actor as shown in Table. no. 3.1 and fifteen test images of different size pixels, are listed in Table No. 3.2 – Fig. No.3.3.

Table 3.1 The PNSR and Bit rate (time) for standard images.

Standard images		Statistical Parameters	BTC	PBTC
Saturn	CR = 0.5616	PSNR	28.78	25.13
		Bit rate Time	0.087	0.039
Rice	CR = 0.5460	PSNR	27.07	24.66
		Bit rate Time	0.097	0.052
Cameraman	CR = 0.5616	PSNR	26.43	23.58
		Bit rate Time	0.096	0.043
Actor	CR = 0.5304	PSNR	30.33	26.44
		Bit rate Time	0.065	0.033

Test images are taken from mobile, webcam and digital camera. The PSNR value is taken as a measure of reconstructed image quality and Bit rate(time) and compression ratio (CR) are measured from compressed image .Values of these statistical images parameters (i.e. PNSR, Bit rate (time), CR) are shown in Table No. 3.1 for standard images and in Table No. 3.2 for test images of different sizes. Plot of values of Bit Rate (time) and CR as shown in Table No.3.2. The algorithms are implemented using MATLAB 7.6.0 (R2008a) on Windows 07 Operating System. The hardware used is the Intel Core i3 2.4 GHz Processor with 2 GB RAM.

Table 3.2 The Bit Rate(time) and Compression Ratio(CR) for test images

Images	**Size in Pixel**	**Bit rate(time)**	**CR**
Image 1	404x406	0.1560	36.0272
Image 2	420x342	0.2964	28.5011
Image 3	343x324	0.2808	54.7233
Image 4	404x406	1.2480	43.1632
Image 5	404x406	0.2966	24.7646
Image 6	697x486	9.4069	47.5450
Image 7	676x470	3.4632	35.6495
Image 8	804x566	1.2948	21.2776
Image 9	697x486	2.0436	29.7429
Image 10	656x470	3.4476	41.4652
Image 11	429x502	1.0452	35.3452
Image 12	676x470	3.4320	13.7933
Image 13	407x406	0.2964	30.0319
Image 14	404x406	0.2808	30.9207
Image 15	404x406	0.2964	24.3479

Table No. 3..3 Comparison of test images with standard images of same size

Images	**Size in Pixel**	**CR**	**Bit rate(time)**
Test Image 1	420x342	5.5588	0.546
Test Image 2	420x342	3.5085	0.5616
Test Image 3	420x342	4.3437	0.546
Test Image 4	420x342	3.2887	0.5616
Test Image 5	420x342	3.0255	0.5772
Test Image 6	420x342	4.2431	0.5616
Test Image 7	420x342	3.0196	0.546
Test Image 8	420x342	2.3543	0.546
Test Image 9	420x342	3.0790	0.546
Test Image 10	420x342	4.1128	0.546
Test Image 11	420x342	3.6166	0.546
Test Image 12	420x342	1.8936	0.546

Test Image 13	420x342	3.8063	0.546
Test Image 14	420x342	3.4253	0.546
Test Image 15	420x342	2.9481	0.546
Saturn	420x342	0.5616	0.039
Rice	420x342	0.5460	0.052
Cameraman	420x342	0.5616	0.043
Actor	420x342	0.5304	0.033

Discussion

Comparison of BTC and PBTC techniques in term of Bit rate (time), PNSR and CR, for standard images as shown in Table No. 3.1, it is clear that the statistical image parameters viz. PNSR, Bit rate (time) and CR are decreased in Parallel BTC as compared to BTC (sequential) technique. It has also been observed that Bit rate (time) parameter is decreased to a greater extent than PSNR in Parallel BTC; therefore Parallel BTC is faster than BTC (sequential). Table 3.2 shows the measured values of Bit rate (time) and Compression Ratio (CR) of 15 test images of different sizes. From Graph No.5.1 it is obvious that the value of CR and Bit Rate (time) depends on size of the image. It found that CR and Bit Rate (time) are maximum for 697x486. In order to compare the statistical image parameters viz. Bit rate (time) and CR of test images with standard image (shown in Table. no. 3.1), image sizes are first made equal. Table No. 3.3 shows the values of Bit rate (time) and CR. Variations in the value of CR and Bit Rate (time) for test images and standard images of equal size

It is obvious from Table No. 3.3 that the statistical image parameters viz. Bit rate (time) and CR for test images and standard images of equal size are found to be comparable but not exactly same. The reason behind it is due to addition of different kinds of noises in test images taken from local sources like Mobile, webcam, digital camera etc.

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