AN EFFICIENT VISUAL PATTERN BLOCK TRUNCATION CODING

Liang-Gee Chen and Yuan-Chen Liu

DSP/IC Design Lab., Department of Electrical Engineering
National Taiwan University, Taipei, Taiwan, R.O.C.
Email: lgchen@video.ee.ntu.edu.tw

ABSTRACT

This paper presents a new practical image coding system, visual pattern block truncation coding (VPBTC). The first idea of this new algorithm is the application of block truncation coding (BTC), which encodes an original image and obtains a bitmap. This bitmap is applied to computing the block gradient orientation and matching the block pattern. Another refinement is that the classification of blocks are based on properties of human visual perception. Blocks are classified into two types: uniform blocks and edge blocks. Not only can VPBTC remove the drawbacks of BTC (e.g. higher bit rate) but also can it repair the defects of VPIC (e.g. mismatching pattern). Four benchmarks prove that the MSE of this algorithm is less than that of VPIC by 37%. Its bitrate, furthermore, is about 60% of BTC's. The advantages of this coding method are fine edge preservation, low computational complexity, and easy implementation.

1. INTRODUCTION

Image coding is getting significant for current applications, for instance, HDTV, multimedia, videophone, video conference and video storage. To remove possible redundancy in the related data is indispensable since there are numerous data to be processed. The most efficient method is data compression. Spatial and/or temporal redundancy are eliminated to accommodate communication or storage. The common techniques for data compression are predictive coding, transform coding, vector quantization (VQ), visual pattern image coding (VPIC), and block truncation coding (BTC), etc.

BTC is an efficient method for block correlated signals. It is a moment preserving quantizer [1]-[6], that is, it quantizes block data into two values by preserving the first moment and the second moment. The advantages of BTC are simple computation, easy implementation and fine edge preservation, etc. The main problem of BTC is its high bitrate. In a fixed block size BTC, the bitrate of BTC is about 1.625 bits per pixel. There are some algorithms [7, 8] which can obtain a lower bitrate and fewer error. However, the computation is complex so that it is hard to implement in VLSI design and in real time processing.

VPIC is a high quality algorithm introduced by P. Chen and A. Bovik [9]. Unlike other algorithms, VPIC uses pixel values in a block to compute block gradient orientation and to select the bilevel block pattern with simple viewing geometry model. Pixels are quantized into two levels by the block mean, gradient magnitude, gradient orientation, and predefined block pattern. High compression ratio is a considerable merit of VPIC. Nevertheless, if a block does not contain an obvious edge, VPIC will mismatch the block pattern. Since VPIC uses the gradient magnitude to classify uniform blocks, it will make serious error when a block contains an edge in a low gray level background.

A new algorithm, visual pattern block truncation coding (VPBTC), is proposed in this paper. BTC is used to encode an original image. This algorithm defines the edge block according to human visual perception. If the difference between the two quantized values of BTC is larger than a threshold which is defined by visual characteristics, it will be defined as an edge block. In an edge block, the bitmap is adapted to compute block gradient orientation and to match the block pattern. Experimental results show that the MSE of the algorithm is less than VPIC by half in the same bitrate. This coding system has many merits such as fair edge preservation, low computation complexity, high compression ratio, easy implementation, and suitable reconstructed image.

In this paper, section 2 briefly reviews BTC and VPIC algorithm. Section 3 discusses how to define the pattern of a block. VPBTC algorithm is presented in section 4. Some simulation results are shown in section 5. Conclusions are given in section 6.

2. PREVIOUS ALGORITHM REVIEW

2.1. Block Truncation Coding

Basic BTC based on moment preserving is a bilevel quantizer. In the original coding scheme, an image is divided into n pel by n line blocks (typically n = 4). Basic BTC uses the mean of the pixel values in a block as the threshold , X_{th}. The basic algorithm computes two quantized values, Y_0 and Y_1, by preserving the first moment and the second moment in each block. The quantized values of Y_0 and Y_1 can be defined as

$$Y_0 = \overline{X} - \sigma\sqrt{\frac{\alpha}{\beta}} \tag{1}$$

$$Y_1 = \overline{X} + \sigma\sqrt{\frac{\beta}{\alpha}} \tag{2}$$

where $\overline{X}$ is the mean of pixel values in a block; σ is the standard deviation of the pixel values in a block; α is the number of X_i which is greater than X_{th}; β is the number of X_i which is less than or equal to X_{th}.

A bitmap records each pixel which belongs to an alternative quantized values. The bitmap, the mean, and the standard deviation need to be transmitted. The bitrate of

0-7803-3073-0/96/$5.00 ©1996 IEEE

basic BTC is 2 bits/pixel. When a two-dimension coding scheme is used [1], the bitrate can be reduced to 1.625 bits/pixel. The coding process of basic BTC takes only a few computation steps. Since basic BTC algorithm bases on preserving statistical moments, the quality of reconstructed image is commendable. Although holding manifold advantages, the main problem of BTC is its low compression ratio. As a result, there is interest in finding a fast algorithm of high compression ratio.

2.2. Visual Pattern Image Coding

VPIC is a high quality algorithm which adapts the pattern of subimage with simple viewing geometry model. The original image being divided into 4×4 blocks, the two directional variations, $\Delta_x b_{i,j}$ and $\Delta_y b_{i,j}$, can be computed from

$$\Delta_x b_{i,j} = AVE(I_{n,m} : 4i+2 \le n \le 4i+3, 4j \le m \le 4j+3) - AVE(I_{n,m} : 4i \le n \le 4i+1, 4j \le m \le 4j+3) \quad (3)$$

$$\Delta_y b_{i,j} = AVE(I_{n,m} : 4i \le n \le 4i+3, 4j+2 \le m \le 4j+3) - AVE(I_{n,m} : 4i \le n \le 4i+3, 4j \le m \le 4j+1) \quad (4)$$

The block gradient magnitude ($|\Delta b|_{i,j}$) and block orientation ($\angle \Delta b_{i,j}$) can be found by the following equations

$$|\Delta b|_{i,j} = \sqrt{(\Delta_x b_{i,j})^2 + (\Delta_y b_{i,j})^2} \quad (5)$$

$$\angle \Delta b_{i,j} = tan^{-1}(\frac{\Delta_y b_{i,j}}{\Delta_x b_{i,j}}) \quad (6)$$

If a block gradient magnitude is larger than a certain threshold, it will be defined as an edge block. VPIC then uses the block gradient orientation to map a block pattern. If it is less than the threshold, the block will be identified as an uniform block. Whenever a block is an uniform block, the encoder will transport the block mean and a header. By contrast, if a block is an edge block, the encoder will transmit the mean, the gradient magnitude, and the index of the block pattern.

The decoder is able to reconstruct images easily by transmitting block pattern, gradient magnitude, header, and block mean. The essential benefit of VPIC is that it catalogues blocks according to human optical perception. VPIC also has the advantages of high compression ratio, fine edge preservation and low computation complexity. Possessing such merits, VPIC still requires efforts to guarantee a more practical solution under several subjective criteria. A chief defect of VPIC is that whenever the edge of a block is not distinct, the algorithm would frequently mismatch the block pattern. Taking figure 1 as example, $\Delta_x b_{i,j}$=3/8, $\Delta_y b_{i,j}$=9/8. The result of the block gradient is computed as 90°. From the bitmap, we can see the correct block orientation is −45°. It obviously mismatches the block pattern. The example manifests that it is significant to find a better VPIC algorithm under subjective criteria.

3. BLOCK PATTERN DECISION

BTC is the most approvable algorithm if the drawback of low compression ratio is remedied. This new BTC based algorithm applies VPIC to reduce the bitrate of BTC. To improve the defects of mismatching patterns by VPIC, we uses the bitmap of BTC to select a block pattern. The process is in the following. First, an image is split into 4×4 blocks. Y_0, Y_1, and the bitmap are obtained after BTC has encoded a 4×4 block. Utilizing the coded bitmap, we find

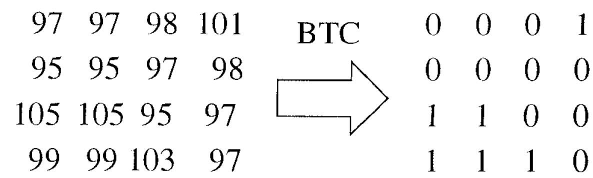

Figure 1. An Example of the mismatching pattern of VPIC.

Δ_x and Δ_y which represent the gradient of x direction and y direction.

$$\Delta_x = SUM(B_{n,m} : 4i+2 \le n \le 4i+3, 4j \le m \le 4j+3) - SUM(B_{n,m} : 4i \le n \le 4i+1, 4j \le m \le 4j+3) \quad (7)$$

$$\Delta_y = SUM(B_{n,m} : 4i \le n \le 4i+3, 4j+2 \le m \le 4j+3) - SUM(B_{n,m} : 4i \le n \le 4i+3, 4j \le m \le 4j+1) \quad (8)$$

Where $B_{n,m}$ is the bitmap of the block. The block gradient orientation can be found out by the following equation

$$\angle \Delta B = tan^{-1}(\frac{\Delta_y B}{\Delta_x B}) \quad (9)$$

After computing the block gradient orientation, we can compare the bitmap with the previously defined block pattern. An index of the most similar block pattern is taken as the index of bitmap.

Four benchmark images are taken as simulation. The d-

TABLE I
THE COMPARISONS OF VPIC AND BVPIC

image	*Block size*	*MSE*		*Ratio*
		VPIC	*BVPIC*	$\frac{BVPIC}{VPIC} \times 100\%$
Lena	4×4	127.58	83.77	65.66%
baboon	4×4	634.62	388.71	61.25%
pepper	4×4	185.19	107.11	57.84%
jet	4×4	279.73	148.04	52.92%

(a) MSE

image	*Block size*	*MAE*		*Ratio*
		VPIC	*BVPIC*	$\frac{BVPIC}{VPIC} \times 100\%$
Lena	4×4	5.90	5.20	88.14%
baboon	4×4	16.29	13.41	82.32%
pepper	4×4	6.58	5.43	82.52%
jet	4×4	7.46	6.42	86.06%

(b) MAE

image	*Block size*	*PSNR*		*Enhancement*
		VPIC	*BVPIC*	$\frac{BVPIC-VPIC}{VPIC} \times 100\%$
Lena	4×4	27.07	28.90	6.76%
baboon	4×4	20.11	22.23	10.54%
pepper	4×4	25.45	27.83	9.35%
jet	4×4	23.66	26.43	11.71%

(c) PSNR

ifference between VPIC and bitmap based VPIC (BVPIC) is the computation of gradient orientation. The gradient orientation of BVPIC is computed by (7) and (8). From Table I, we could find that the BVPIC is more accurate than VPIC. Since computing of block gradient orientation counts the number "1" of bitmap only, the computation complexity is reduced in comparison with VPIC.

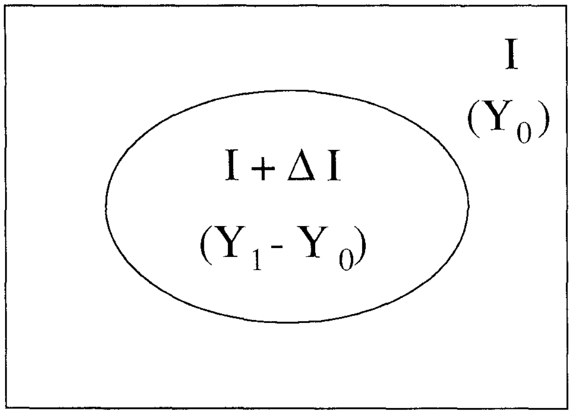

Figure 2. Contrast sensitivity measurement.

4. VISUAL PATTERN BLOCK TRUNCATION CODING

Two types of blocks, uniform blocks and edge blocks, are usually classified by using block variance. There are several methods of defining blocks. We propose that the identification of a block should base on the characteristics of human vision. After the encoding process of BTC, there are two quantized values whose difference represents the changes in the intensity of illumination of a block. According to the Weber-Fechner Law [10], the quotient of the fraction of illuminative intensity in a region is an essential reference for human visual perception. The sensible stimulus for human eyes to the changes of illumination, the contrast sensitivity, is dependent on the intensity of the surrounding. As figure 2 shows, a given patch of light of intensity I+ΔI surrounded by a background of intensity I.

The sensible difference for normal human eyes ΔI is to be determined as a function of I. The ratio ΔI/I, known as Weber fraction, is almost constant at the value about 0.02 [10]. Recognizing the value of minimum contrast sensitivity of human eyes, we define the block whose difference of illuminative intensity is perceivable as an edge block and the imperceptible one as an uniform block. Let the difference between Y_1 and Y_0 be ΔI, and Y_0 be the background I. If the quotient of $Y_1 - Y_0$ and Y_0 is less than 0.02, the block is an uniform block. Otherwise, it is an edge block. The flowchart of VPBTC is shown in figure 3 and its procedures are described as follow:

1. An image is divided into n pel by n line blocks (typically n = 4).
2. The block is coded by BTC.
3. If the ratio of $Y_1 - Y_0$ and Y_0 is less than 0.02, it is an uniform block. Otherwise, it is an edge block.
4. If it is edge block, the bitmap is used to decide the block pattern by bitmap based VPIC.
5. The quantized values or mean are transmitted and so is the index of the block pattern.

5. SIMULATION RESULTS

Four benchmarks are used as test examples. Table II shows the results of various algorithms. The bitrate is fixed in about 0.9 bit per pixel. VPBTC(1) takes the block mean as the threshold and Y_0, Y_1 as the quantized values of moment preserving. VPBTC(2) uses mean as the threshold of BTC. Y_0 and Y_1 are set as the lower mean and the upper mean respectively. VPBTC(3) is OBTC presented by Chen and Liu [8]. The reconstructed image of new algorithm 2 is shown in figure 4.

6. CONCLUSION

This paper proposes a new developed image coding system, VPBTC, which not only removes the drawbacks of BTC and VPIC but also maintains their advantages. The system surpasses the VPIC in accuracy, arithmetic simplicity and hardware implementation. Furthermore, we also offer an visual based BTC algorithm which outdoes BTC in bitrate and image quality. Four benchmark images are tested to verify the performance. The experimental results show that the proposed system are superior to other algorithms. In addition, the regularity and simplicity of the VPBTC algorithm manifest that it is quite suitable for an efficient VLSI implementation when used in a low bit rate video coder. A systolic architecture on real video codec system is currently under development for real-time application.

REFERENCES

[1] E. J. Delp and O. R. Mitchell, "Image compression using block truncation coding," *IEEE Trans. Commun.*, vol. COM-25, no. 9, Sept. 1979, pp. 1335-1342.

[2] O. R. Mitchell and E. J. Delp, "Multilevel graphics representation using block truncation coding," *Proc. IEEE*, vol. 68, no. 7, July 1980, pp. 868-873.

[3] D. R. Halverson, N. C. Griswold, and G. L. Wise, "A generalized block truncation coding algorithm for image compression," *IEEE Trans. Acoust., Speech, Signal Processing*, vol. ASSP-32, no. 3, June 1984, pp. 664-668.

[4] L. G. Chen, Y. C. Liu, T. D. Chiueh, and Y. P. Lee, "A real-time video signal processing chip," *IEEE Trans. Consumer Electronics*, vol. 39, no. 2, may 1993, pp. 82-92.

[5] T. P. Chan, B. Zeng, and M. L. Liou, "BTC image coding with visual patterns," in *Proc. APCCAS'94 Conf.*, Grant Hotel, Taipei, Dec. 1994, pp. 12C.8.1-12C.8.6.

[6] V. R. Udpikar and J. P. Raina, "Modified algorithm for block truncation coding of monochrome images," *Electron. Lett.*, vol. 21, no. 20, Sept. 1985, pp. 900-902.

[7] M. Kamel, C. T. Sun, and Lian Guan, "Image compression by variable block truncation coding with optimal threshold," *IEEE Trans. Signal Processing*, vol. 39, no. 1, January 1991, pp. 208-212.

[8] L. G. Chen and Y. C. Liu, "A high quality MC-BTC codec for video signal processing," *IEEE Trans. Circuits and Systems for Video Technology*, vol. CSVT-4, no. 1, Feb. 1994, pp. 92-98.

[9] D. Chen and A. C. Bovik, "Visual Pattern Image Coding," *IEEE Trans. Commun.*, vol. COM-38, no. 12, Dec. 1990, pp. 2137-2146.

[10] W. K. Pratt, *Digital Image Processing.* New York: John Wiley & Sons, Inc, 1991.

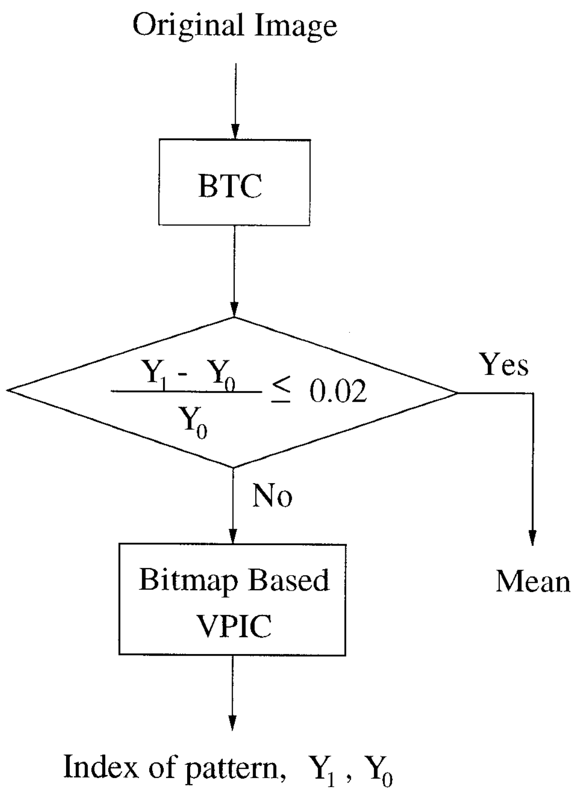

Figure 3. Flowchart of VPBTC.

TABLE II
THE PERFORMANCE OF VPBTC

Image	*VPIC*	*VPBTC(1)*	*VPBTC(2)*	*VPBTC(3)*
Lena	127.80	58.31	52.29	51.02
baboon	634.63	415.77	365.88	364.29
pepper	185.35	55.13	48.93	47.84
jet	279.81	74.00	67.14	61.84

(a) MSE

Image	*VPIC*	*VPBTC(1)*	*VPBTC(2)*	*VPBTC(3)*
Lena	5.96	4.21	4.05	3.93
baboon	16.29	12.95	12.14	11.84
pepper	6.61	4.34	4.11	3.99
jet	7.50	3.86	4.04	3.86

(b) MAE

Image	*VPIC*	*VPBTC(1)*	*VPBTC(2)*	*VPBTC(3)*
Lena	27.07	30.41	30.95	31.05
baboon	20.11	21.94	22.50	22.52
pepper	25.45	30.72	31.24	31.33
jet	23.66	29.44	29.86	30.22

(C) PSNR

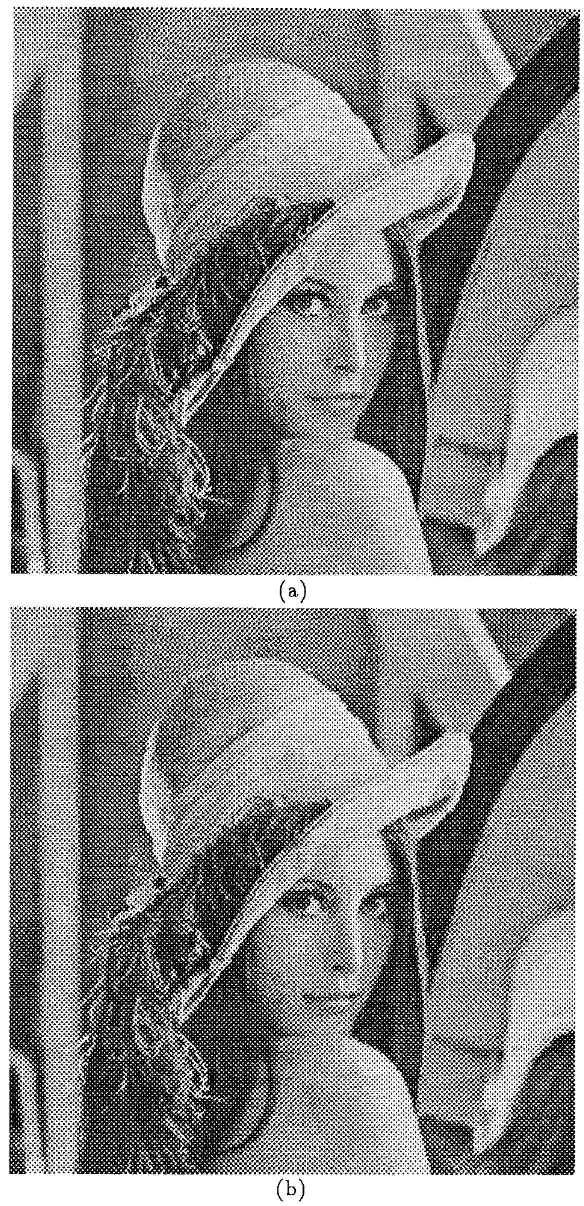

Figure 4. Result of VPBTC algorithm. (a) Original image is 512×512 pixels with 8 bits gray level resolution; (b) Coded image using VPBTC(2).