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Implementation of Adaptive Coding Approach Based on Periodic Walsh Piecewise-Linear Transform for Digital Grayscale Image

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Abstract

An adaptive coding technique of gray level images using Periodic Walsh Piecewise-Linear (PWL) transform will be presented in this paper. In this technique the image sub-blocks are divided into four classes according to the level of image activity. The ac energy is used as a measure of the sub-block activity. Adaptivity is obtained by distributing bits among glasses. More bits are assigned to classes of higher activity and fewer bits to lower activity classes. The coding method employs an integer bit allocation scheme and Llyod-Max quantizers. Comparison of coding real images using the adaptive and non-adaptive schemes is given. Computer simulation results indicate that the image coding efficiency using the adaptive technique gives better performance than the non-adaptive scheme from the Peak Signal-to-Noise Ratio (PSNR) viewpoint of the reconstructed images at the expense of a slight increase in complexity.

Keywords: An adaptive coding, (PWL), image, bit ,(PSNR).

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تطبيق طريقة تكييفية للترميز تعتمد على تحويل ولش الدوري المتقطع لضغط الصور الرقمية ذات التدرج الرمادي

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الملخص

في هذه الورقة سوف يتم عرض طريقة تكيفية للترميز تعتمد على تحويل ولش الدوري المتقطع. في هذه الطريقة يتم تجزئة الصورة الى عدة مقاطع فرعية، كل مقطع يتم تقسيمه الى أربع فئات بناءً على مستوى نشاط الصورة، لذا تُستخدم طاقة التيار المتردد كمقياس لنشاط المقطع الفرعي بحيث يتم الحصول على التكيف من خلال توزيع البتات على الفئات الاربع. يتم تخصيص عدد اكبر من البتات للفئات ذات النشاط الأعلى وعدد أقل من البتات للفئات ذات النشاط الاقل، بعد ذلك يتم استخدام مكممات تخصيص البت الصحيح وليود ماكس (Llyod Max).

تم ترميز بعض الصور الحقيقية باستخدام الطرق التكيفية وغير التكيفية، النتائج المتحصل عليها من برنامج المحاكاة الحاسوبي تشير إلى أن كفاءة ترميز الصور باستخدام الطريقة التكيفية أفضل من الطريقة غير التكيفية من ناحية قيم نسبة الإشارة إلى الضوضاء القصوى (PSNR) للصور المسترجعة مع زيادة طفيفة في درجة التعقيد.

I. Introduction

Research in the field of image coding has been going for more than four decades. Many terms have been used to describe this particular area of image processing such as image compression, bandwidth reduction, redundancy reduction, etc. The fundamental purpose of data compression is to reduce the bit rate for transmission or data storage while maintaining an acceptable fidelity or image quality. Today's applications of image compression range from transmission of moving images (such as television and teleconferencing) to still image applications such as electronic facsimile as well as other applications of gray-scale and color images. There are generally two basic techniques for image data compression: *Spatial Coding* and *Transform Coding.* Spatial coding is carried out in the data domain ,e.g., differential pulse code modulation (DPCM) [8] and Block Truncation Coding (BTC) [6-12]. Transform coding is a transform domain process which involves an energy preserving mapping of the original image data such that the maximum information is preserved in a minimum number of samples or coefficients [7]. The rest of samples can often be discarded entirely, or coded with a small number of code symbols with only negligible image distortion.

Adaptive transform coding based on the statistics of the image data is considered to be as very effective and practical, however, it introduces system complexity. The key to practical system implementation lies in selecting an efficient coding scheme which achieves a compromise between complexity and performance. In this paper an adaptive coding technique using the periodic Walsh piecewise-linear transform is described. Image blocks are sorted into classes according to the level of activity. Bits are distributed between image sub-blocks to provide the desired adaptivity, Sub-blocks of high activity are assigned more bits than those of lower activity. The coding bits are allocated to transform coefficients according to the variance matrix of transformed data of each class.

In this paper, I will present the results of adaptive coding of real images using Periodic Walsh Piecewise-Linear PWL transform. The PWL functions and transform are briefly described in section II. Section III contains a description of the adaptive coding system using the PWL transform. Simulations and experimental results are introduced in section IV. Concluding remarks are drawn in section V.

II. Periodic Walsh Piecewise-Linear Functions and Transform

The Periodic Walsh piecewise-Linear PWL functions which are the basis functions of the PWL transform [1-4] are obtained by integrating periodic Walsh functions as follows:

$$PWL(0,t) = 1, t \in (-\infty, \infty) \qquad (1a)$$

$$PWL(i,t) = \frac{2^{k+1}}{T} \int_{mT}^{t+mT} Wal(i,\tau)\, d\tau \qquad (1b)$$

where :

i = l,2,…, N-1., k = 1,2,...,$\log_2$ N., *m*=0,1,2,...

k is the group index of PWL functions and *m* is the number of period. The matrix form of the forward and inverse PWL transforms may be formulated as follows:

a) Forward transform [C(N)]=[$-2^{-(k+1)}$][PWL(N)][X(N)] (2)

b) Inverse transform [C(N)]=[IPWL(N)][C(N)] (3)

where :

[C(N)] - vector of PWL coefficients.

[X(N)] - vector of sampled signal.

[PWL(N)] - matrix of forward transform.

[IPWL(N)] - matrix of inverse transform.

[$-2^{-(k+1)}$] - diagonal matrix of normalization.

A two-dimensional piecewise linear transform is performed by sequential row and column transformations as follows:

$$[V]=[PLT]\ [U]\ [PLT]^T \qquad (4)$$

$$[U]=[IPWL][V][IPWL]^T \qquad (5)$$

where :

[V] - NxN matrix of spectral coefficients.

[U] - NxN matrix of data.

[IPWL] - NxN inverse Piecewise-Linear transform matrix.

[PLT] - NxN transform matrix, where [PLT] = [$-2^{-(k+1)}$][PWL].

III. Adaptive Coding of Images

Before transforming the image sub-blocks, they are classified according to level of activity (ac energy) such that each class will have the same number of sub-blocks. The classification of the image sub-blocks into equally populated levels provides a simple way to ensure that the average coding over the whole image is maintained. The number of classification levels is generally dependent upon the image size, the degree of activity of the image and the bits required to code the compressed data. To decide which class a particular block belongs to, we first measure the variance of each block within the image relative to its local mean. If the intensity of the pixels in the *n-/h* block are denoted by *u(i,j)* and the block size is NxN, then the local mean is given as;

$$m_n = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} u(i,j) \qquad (6)$$

and the block variance is;

$$\sigma_n^2 = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{J=0}^{N-1} [u(i,j) - m_n]^2 \qquad (7)$$

The variances are then arranged in increasing order and thresholds are determined so that they can be separated into four groups each containing *25%* of the variances and the corresponding blocks are then labeled as belonging to one of the four classes. All classification indexes have to be sent to the receiver end as part of overhead information which will be used to decode the received data. This corresponds to an overhead rate of $(2/N^2)$ bits per pixel.

Having the desired overall bit rate, the average variances of the classes are used to find the average bit rate for each class. The variance of each coefficient in each class is then calculated and used together with the integer bit allocation algorithm [l1] to determine a bit allocation map for each class.

Before the PWL coefficients are quantized they are normalized by a normalization coefficient (in order to use the same unit variance quantizer for a given bit allocation) and a corresponding inverse normalization step has to be carried out at the decoder. In order not to send a normalization factor for each coefficient in each class, a normalization coefficient has to derived at both coder and decoder. Chen and Smith [3] used a normalization coefficient given by:

$$\sigma_k'(i,j) = c.2^{N_{B_k}(i,j)} \qquad (i,j) \neq (0,0) \qquad (8)$$

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where k is class index, $N_{B_k}(i,j)$ is the number of bits assigned to the transform coefficient, and c is a normalization factor which is determined during the bit assignment process by making it equal to the maximum standard deviation of those elements in the variance matrix which were assigned to one bit. From the investigations, it has been found that using a normalization factor given by:

$$c = 0.5.max\{\sigma_k(i,j)\} \quad (9)$$

gives the best results for the PWL transform in terms of the PSNR of the reconstructed image. Next, the normalized coefficients are optimally quantized with the number of quantization levels set according to the bit allocation matrices.

It is also necessary to transmit some overhead information to the decoder and this overhead consists of: the sub-block classification map (4 classes), the normalization factor *c*, and four bit allocation maps. The total is around 0.05 bits/pixel for the case when the average bit rate is 1 bit/pixel. Block diagrams of PWL adaptive coder and decoder are shown in Fig. 1. and Fig. 2, respectively.

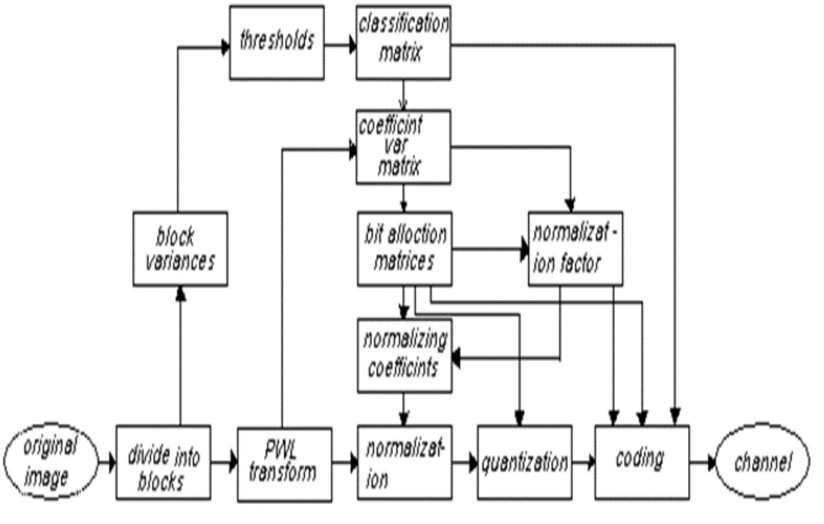

Fig 1. PWL adaptive image coding system; (coder)

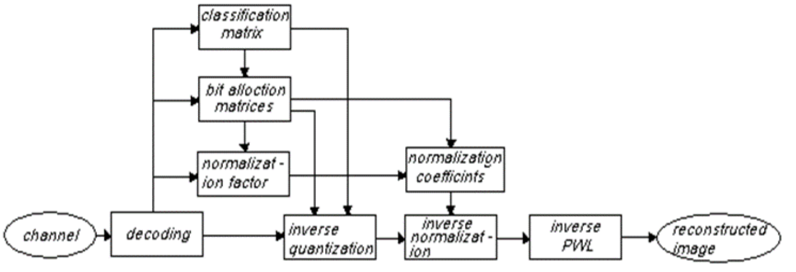

Fig 2. PWL adaptive image coding system; (decoder)

IV. Experimental Results

A series of computer simulations have been conducted to evaluate the performance of PWL adaptive coding of some test images. The test images which have been used in this investigation contain 256x256 pixels with 8-bit resolution per pixel. A block size of 16x16 is used.

In order to distinguish between blocks that are active and those that are smooth, we have used four classes where class 1 is the most active and class 4 is the smoothest. Fig. 3. illustrates the classification map for the test image (girl).

Fig. 4. shows the bit allocation matrices for the same test image at a bit rate of 2 bpp. It should be pointed out at this stage that at low bit rates some classes, particularly classes 3 and 4 will be assigned zero bits. In order to improve the PSNR and the quality of reconstructed image in such cases, the dc coefficient is always assigned 8 bits. Table I. shows the number of bits assigned to each class at different bit rates. Figs. 5. and 6. show the results of four-class adaptive PWL transform coding as applied to the test images with different coding rates. Table 2. shows a comparison of 2D non-adaptive, and 2D adaptive PWL coding of the test image girl.

2 2 4 4 4 3 3 4 3 4 4 4 4 4 3 3
4 4 4 4 2 2 2 3 3 3 3 3 3 3 3 3
4 2 4 2 2 3 3 2 2 4 2 3 4 4 2 2
3 4 2 3 2 2 2 3 4 4 1 4 4 4 2 3
2 2 2 3 1 2 3 2 2 2 1 4 4 4 1 3
2 3 3 3 1 2 3 3 2 1 2 3 4 4 1 3
3 2 3 3 3 2 3 3 4 1 1 1 4 4 1 3
2 4 2 1 3 1 2 3 3 2 1 1 4 4 1 3
3 2 2 1 1 1 3 2 3 1 1 1 4 4 1 3
2 2 2 1 1 3 2 4 4 3 2 1 4 4 1 3
3 2 4 1 1 2 1 3 1 1 1 1 1 2 4 3
1 4 4 2 2 2 1 1 1 2 1 1 3 4 1 3
3 4 4 1 3 4 2 1 1 1 2 1 1 4 1 4
4 4 1 1 3 2 1 2 1 1 2 2 1 4 2 4
4 3 1 4 3 2 3 1 2 1 1 2 1 4 4 3
4 1 2 4 4 3 3 2 2 2 1 1 1 4 4 2

Fig 3. The classification map for the test image (girl) with block size of 16x16
(1 indicates the highest activity blocks and 4 the lowest activity blocks)

8 7 6 5 5 5 5 4 4 4 4 4 4 4 4 3
5 6 6 5 5 5 5 4 4 4 4 4 3 3 4 2
5 5 6 5 5 5 5 4 4 4 4 3 4 4 4 2
4 5 5 5 5 4 4 3 3 3 3 3 3 3 3 2
4 5 5 4 5 4 4 3 3 3 3 3 3 2 3 1
4 5 5 4 4 5 4 3 3 3 4 3 3 3 3 2
4 5 5 5 5 5 5 4 3 4 3 3 3 3 3 2
3 4 4 4 4 3 4 2 3 3 2 3 3 2 2 1
3 4 4 4 4 4 4 3 3 3 2 2 2 3 2 1
3 4 4 3 3 4 4 3 3 3 3 2 2 2 2 1
3 4 4 3 3 4 3 2 2 2 3 3 2 2 2 1
3 3 3 3 3 3 3 2 2 2 2 3 3 3 2 1
3 3 4 3 3 3 3 2 2 2 3 3 3 2 2 1
3 4 4 3 3 3 3 2 2 2 2 2 2 2 3 1
3 4 4 3 3 3 3 2 2 2 2 2 2 3 2 1
2 2 2 2 2 2 2 1 1 1 1 1 1 1 1 0

(a) class 1

8 5 5 4 4 4 4 3 3 3 3 3 3 3 3 2
5 5 4 4 4 4 4 3 3 3 3 3 3 3 3 2
5 5 5 4 4 4 4 2 3 3 3 2 3 3 3 2
4 4 4 3 4 3 3 2 2 2 2 2 2 2 2 1
4 4 4 3 3 3 3 2 2 2 2 2 2 2 2 1
4 4 4 4 4 4 3 3 3 3 3 2 2 3 2 1
4 4 4 3 3 4 4 3 3 3 2 2 2 3 2 2
2 3 3 3 2 3 2 2 2 2 2 1 2 2 1 1
3 3 3 2 2 2 3 2 2 2 2 2 2 2 2 1
3 3 3 2 2 3 3 2 2 2 2 2 2 2 2 0
2 3 3 2 2 2 3 1 2 2 2 2 1 2 1 0
3 3 3 2 2 3 2 2 2 2 2 1 2 1 2 0
3 3 3 2 2 3 3 1 1 2 2 2 2 2 2 1
2 3 2 2 2 2 2 2 1 2 2 2 2 2 2 1
3 3 3 2 2 2 2 1 1 1 2 1 2 2 2 1
2 2 2 1 1 1 1 0 0 0 1 0 1 1 1 0

(b) class 2

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Volume 34 العدد
Part 2 المجلد
July 2024 يوليو

تم استلام الورقة بتاريخ: 29/ 2024/6م

وتم نشرها على الموقع بتاريخ: 31/ 2024/7م

8 4 4 4 4 3 3 3 3 2 2 2 2 2 2 1
4 3 4 3 3 3 3 2 2 2 2 2 2 2 2 2
4 4 4 3 3 3 3 2 2 2 2 2 2 2 2 1
3 3 3 2 2 2 2 2 1 1 2 2 1 1 2 1
3 3 3 2 2 3 2 2 2 1 1 1 2 2 2 1
3 3 3 2 3 3 3 2 2 2 2 2 2 2 2 1
3 3 3 2 2 2 2 2 2 2 2 2 2 2 2 1
2 2 2 2 1 1 2 1 1 1 1 1 1 1 1 0
2 2 2 1 1 2 2 1 1 1 1 1 1 1 1 0
2 2 2 2 1 2 2 1 1 1 1 1 1 1 1 0
2 2 2 1 1 2 2 1 1 1 1 1 1 1 1 0
2 2 2 1 1 2 2 1 1 1 1 1 1 1 1 0
2 2 2 2 2 2 2 1 1 1 1 1 1 1 1 0
2 2 2 1 1 2 2 1 1 1 1 1 1 2 1 0
2 2 2 2 1 2 2 1 1 1 1 1 1 1 1 0
1 1 1 0 0 1 1 0 0 0 0 0 0 1 0 0

(c) class 3

8 3 2 2 1 2 1 1 1 1 1 1 1 1 1 0
2 2 2 1 1 1 2 1 1 1 1 1 1 1 1 1
2 2 2 1 2 2 2 1 1 1 1 1 1 1 1 1
1 1 1 1 0 1 1 0 0 1 0 0 0 1 1 0
1 2 1 1 1 1 1 0 0 1 1 1 1 1 1 0
1 2 2 1 1 2 2 1 1 1 1 1 1 1 1 0
1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0
0 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0
0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0
0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0
0 1 1 0 0 0 1 0 0 0 0 0 0 0 0 0
1 1 1 0 0 1 1 0 0 0 0 0 0 0 1 0
0 1 1 1 1 1 1 0 0 0 0 0 0 1 1 0
0 1 1 1 0 1 1 0 0 0 0 1 1 1 1 0
0 1 1 0 1 1 1 0 0 0 0 0 0 1 1 0
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0

(d) class 4

Fig 4. Bit allocation matrices for each class of test image (girl) at bit rate of 2 bpp

Table 1. Distribution of bits between different classes for adaptive PWL at different bit rates

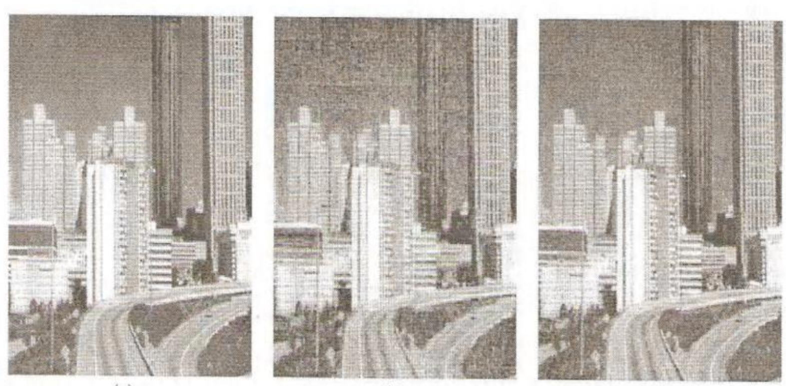
bit rate	dc bits	ac bits							
		Girl				City			
		class 1	class 2	class 3	class 4	class 1	class 2	class 3	class 4
1	8	522	330	140	0	461	368	163	0
2	8	810	617	427	162	753	660	456	146
3	8	1066	73	683	418	1009	916	712	402

Table 2. Comparison of PWL coding results of girl using adaptive and non-adaptive schemes

bit rate	PSNR (dB)	
	non-adaptive	Adaptive
1	25.38	28.08
2	29.56	32.97
3	33.79	37.49

(a) (b) (c)

Fig.5. reconstructed test image girl using PWL transform adaptive coding: (a) Original, (b) 1 bpp, and (c) 2 bpp



(a) (b) (c)

Fig 6. Reconstructed test image city using PWL transform adaptive coding: (a) Original, (b) 1 bpp , and (c) 2 bpp

V. Conclusion

An adaptive coding scheme of gray level images using the Periodic Walsh Piecewise Linear transform has been investigated in this paper. This scheme is based on the classification of the image sub-blocks by activity level. An integer bit allocation scheme and Llyod-Max quantizers have been used. Comparison of coding real images using the adaptive and the non-adaptive schemes is analyzed. It has been shown that the image coding efficiency of the adaptive coding is better than the non-adaptive coding.

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References:

[1] Belgassem . F. *"Image and Contour data Compression using Periodic Piecewise Linear Transforms"*. Ph.D. Thesis, Faculty of Electrical Engineering, University of Mining and Metallurgy, Cracow, Poland, 1997.

[2] Castleman, K.R., "*Digital Image Processing*." Second ed. 1996, Englewood Cliffs, New Jersey: Prentice-Hall.

[3] Chen W-H., Smith H "Adaptive Coding of Monochrome and Color Images" *IEEE Trans. on Comm.*, vol.25, No.11, Nov. 1977, pp.1285-1292

[4] Dziech A, Kwater M "Fast Transforms Based on Piecewise-Linear Functions" IEEE *Workshop on ASSP*, Beijing 1986.

[5] Farrelle P M , *Recursive Block Coding for Image Data Compression*, Springer-Verlag, NY,1990.

[6] Healy D. 3. Mitchell 0. R. ", Digital Video Bandwidth Compression using BTC", *IEEE Trans. on Commun.*, vol.COM-29, 1981, pp.1809-1817.

[7] Jam A. K. "Image Data Compression: A Review? *Proc. of IEEE*, vol.69, No.3, March 1981, pp.349-389.

[8] Jayant N S, Noll P , *Digital Coding of Waveforms*, Prentice-Hall, Englewood Cliffis, NJ, 1984.

[9] Rafeal. C. Gonzalez, Richard.E Woods P, Digital *Image Processing*, 3rd. edition, Addisson-Wesley, 2008.

[10] Rao K. R., Yip P , *Discrete Cosine Transform*, Academic Press, NY, 1990.

[11] Seddeq E. Ghrare; Ahmed R. Khobaiz, "Digital image compression using block truncation coding and Walsh Hadamard transform hybrid technique", The 2014 IEEE International Conference on Computer, Communications, and Control Technology (I4CT) , 02-04 September 2014, Langkawi, Malaysia

تم استلام الورقة بتاريخ: 29/ 6/2024م وتم نشرها على الموقع بتاريخ: 31/ 7/2024م

[12] Udpikar V. R., Raina J. P. ,,BTC Image Coding using Vector Quantization" *IEEE Trans. on Coinmun., vol.35,* No.3, Mar.1987, pp.352-356.

[13] Yà. V. Luts and V. K. Luts, "About the development of a high-speed simplified image codec," Cybernetics and Computer Technologies, Issue 1, pp. 61–66 (2021).