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Linear Polynomial Coding with Midtread Adaptive Quantizer

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Abstract
In this paper, a hybrid image compression technique is introduced that integrates discrete wavelet transform (DWT) and linear polynomial coding. In addition, the proposed technique improved the midtread quantizer scheme once by utilizing the block based and the selected factor value. The compression system performance showed the superiority in quality and compression ratio compared to traditional polynomial coding techniques.

Keywords: Image compression, polynomial coding, and midtread adaptive quantizer.

متعدد الحدود الخطي مع وسط الخطوة المعدل التكميمي

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الخلاصة
في هذا البحث, تم تقديم تقنيه هجينه لضغط الصور تعتمد على الدمج بين التحويلات المويجيه و متعدد الحدود الخطي. بالاضافه الى ان التقنيه المقترحه طورت على نموذج وسط الخطوه التكميمي مره باستخدام البلوك ومره باستخدام قيمه معامل مختار. نتائج الاداء بينت تفوق نظام الضغط المقترح من حيث نسبه الضغط وجوده الصوره مقارنه مع نظام متعدد الحدود التقليدي.

1. Introduction

Image compression is an attractive multimedia area to researcher, in which transmission and storage in data bases essential to save time and cuts costs. Today, there are well known international standards like JPEG and GIF used for example in web, even there's increased needs to deliver other techniques, but most of them still under development like predictive coding and fractal [1].

Image compression basically based on removing the observed and/or unobserved redundancies between the embedded observed pixels (i.e., interpixel redundancy) the unobserved of representation of pixel values using the fixed length binary coded (i.e. coding redundancy) and the unobserved of human visual system (i.e., psychovisual redundancy) where the techniques simply classified into lossless and lossy depending on the redundancy(s) way exploited [2], review of various image compression techniques can be found in [3-7].

Polynomial coding constitutes one of the new promising image compression techniques, alternative to predictive coding, that characterized by simplicity, efficiency, and standardized the modelling formula, which adopted by a number of researchers such as in [8-12].

In this paper, an efficient hybrid method is introduced that integrates the multiresolution scheme of DWT base along with linear polynomial coding and midtread adaptive quantizer. The rest of paper organized as follows, section 2 contains comprehensive clarification of the proposed system; the results for the proposed system is given in section 3, and the conclusion in section 4.

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2. Proposed System

The general form of polynomial coding framework simply composed of image modelling or prediction and differentiation (residual), but at the expense of residual size that implicitly affect the compression results. The proposed technique is based on improving the polynomial coding technique by exploring the efficient residual quantizer method along with DWT of soft thresholding base as explained in the following steps; also the layout is illustrated in Figure-1:

Step 1: Load the input uncompressed image I of size N×N that corresponds to high resolution image.

Step 2: Perform wavelet transform that decompose I image into four quadrants of approximation and detail sub bands (I_{LL}, I_{LH}, I_{HL} and I_{HH}) respectively, each of size ($N/2\times N/2$), where the approximation sub bands corresponds to significant part (i.e. average image of low frequency sub bands), while the details sub bands corresponds to insignificant part (i.e. horizontal edges, vertical edges and diagonal edges respectively).

Step 3: For the approximation sub bands (I_{LL}), apply the linear polynomial coding techniques of lossy base that composed following sub steps:

a) Create the predicted image $I_{\tilde{L}L}$, by first partitioning the approximation sub bands I_{LL} into nonoverlapping blocks of fixed size $n\times n$ to compute the coefficients, and quantize/dequantize the coefficients such as [8,9]:

$$a_0 = \frac{1}{n \times n}\sum_{i=0}^{n-1}\sum_{j=0}^{n-1} I_{LL}(i,j)$$

$$a_1 = \frac{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1} I_{LL}(i,j)\times(j-x_c)}{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(j-x_c)^2} \quad \text{..........} \quad ...(1)$$

$$a_2 = \frac{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1} I_{LL}(i,j)\times(i-y_c)}{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(i-y_c)^2}$$

$$a_0Q = round\left(\frac{a_0}{QS_{a0}}\right) \rightarrow a_0D = a_0Q \times QS_{a0}$$

$$a_1Q = round\left(\frac{a_1}{QS_{a1}}\right) \rightarrow a_1D = a_1Q \times QS_{a1} \quad \text{..........} \quad (2)$$

$$a_2Q = round\left(\frac{a_2}{QS_{a2}}\right) \rightarrow a_2D = a_2Q \times QS_{a2}$$

$$I_{\tilde{L}L} = a_0D + a_1D(j-x_c) + a_2D(i-y_c) \text{.....}(3)$$

Where $xc = yc = \frac{n-1}{2}$ and n is the block size. Also the a_0 coefficients represent the block mean, the a_1 coefficients and a_2 coefficients represent the ratio of sum pixel multiplied by the distance from the center to the squared distance in i and j coordinates respectively. The $a0Q, a1Q, a2Q$, $a0D, a1D, a2D$ corresponds to quantized/dequantized steps of the computed coefficients, using the coefficients quantization steps $QSa0$, $QSa1$, $QSa2$.

b) Find the residual or differentiation between the original low resolution approximation sub-band (I_{LL}) and the predicted one $I_{\tilde{L}L}$.

$$R(i,j) = I_{LL}(i,j) - I_{\tilde{L}L}(i,j) \text{.......}(4)$$

c) Quantize the residual image using the Midtread adaptive quantizer [13] of seven levels quantization.

$$q(R)=\begin{cases}\Delta 2 & \alpha 2 \le R\\ \Delta 1 & \alpha 1 \le R < \alpha 2\\ \Delta & \alpha \le R < \alpha 1\\ 0 & -\alpha \le R < \alpha\\ -\Delta & -\alpha \ge R > -\alpha 1\\ -\Delta 1 & -\alpha 1 \ge R > -\alpha 2\\ -\Delta 2 & -\alpha 2 \ge \end{cases} \quad ....\quad ..(5)$$

Where

$$\begin{aligned}\Delta &= D\,\sigma_R\\ \Delta 1 &= D1\,\sigma_R\\ \Delta 2 &= D2\,\sigma_R \quad .... \quad .(6)\\ \alpha &= B\,\sigma_R\\ \alpha 1 &= B1\,\sigma_R\\ \alpha 2 &= B2\,\sigma_R\end{aligned}$$

σ_R Residual Standard deviation

$$B=\begin{cases} KB & \sigma_R > \sigma_{min}\\ KB\dfrac{\sigma_{min}}{\sigma_e} & \sigma_R \le \sigma_{min}\end{cases} \quad ....(7)$$

$$\begin{aligned}B1 &= B + KB1\\ B2 &= B + Kb2\\ D &= B + Kd ....(8)\\ D1 &= B + KD1\\ D2 &= B + KD2\end{aligned}$$

Where KB, KB1, KB2 and KD, KD1, KD2 are constants such as KB = 0.8, KB1 = 1.0, KB2 = 1.8 , KD = 0.5, KD1 = 1.4, KD2 = 2.1

The quantized residual along with the compressed information of quantized coefficients, and standard deviation compressed using Huffman coding technique.

Step 4: For the details sub bands (I_{LH}, I_{HL} and I_{HH}) of less significance information; generally, they can be set to zero without significantly changing the image [14], here the soft thresholding base utilized, such as [15]:

$$\det ails_Q=\begin{cases} Sign(derails)(|\det ails| - Thresold) & if\ |\det ails| > Threshold\\ 0 & else\end{cases} \quad ....(9)$$

The quantized details sub bands compressed using the Huffman coding technique.

To reconstruct the decompressed image, first reconstruct the approximation sub bands by adding the quantized residual to the prediction, such that:

$$\hat{L}L(i,j) = q(R)(i,j) + \tilde{L}L(i,j) ....(10)$$

The lossy detailed sub bands of soft thresholding base (I_{LH}, I_{HL} and I_{HH}) used in the inverse wavelet transform to reconstruct the compressed (decoded) image $\hat{I}$.

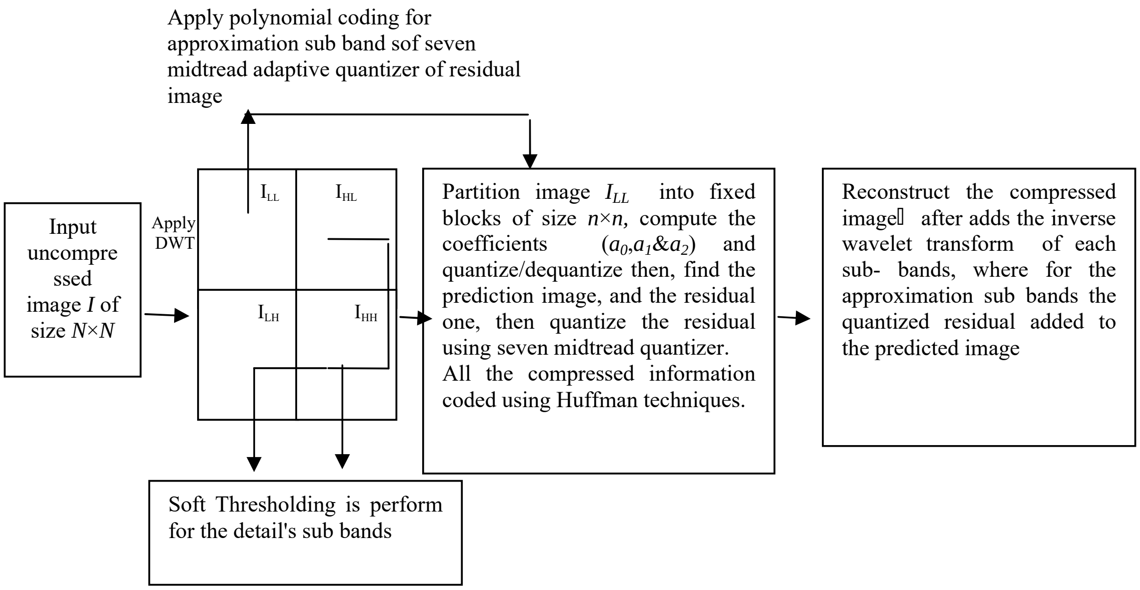

Figure 1-The proposed compression system structure.

3. Experimental Results

The standard images will be used to test the performance of the proposed system are Lena (fig 2.a), Rose (fig 2.b) and Pepper (fig 2.c), all the original uncompressed images are square images of *256* gray levels (*8* bits/pixel) of size *256×256*. The fidelity criteria of objective base used to evaluate the reconstructed image quality (decoded image) of *PSNR* measure [16].

$$PSNR\ (dB) = 10\ \log_{10}\left[\frac{(\max imumgray\ \ scale\ \ of\ \ image)^2}{MSE}\right] \qquad (11)$$

$$MSE\ (I,\hat{I}) = \frac{1}{N \times N}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}[\hat{I}(i,j) - I(i,j)]^2 \qquad (12)$$

Also, the compression ratio (*CR*) will be used to measure the data compression, which generally is the ratio of the original image size to the compressed size [16].

The results shown in Tables-(1, 2) compared the traditional polynomial coding and the proposed techniques of seven quantization levels of tested images using block sizes of *4×4*. For the traditional polynomial coding technique the quantization steps of coefficients are adopted to be *1*, *2*, *2* for a_0, a_1, and a_2 respectively, with various quantization levels (steps) of residual selected to be between *5* to *50*. On the other hand the proposed system utilized only seven equalization levels of residual image, and the threshold values of details sub bands computed as the ratio of number of nonzero element to number of zero element of each sub bands [17].

Table 1-The performance of the traditional polynomial coding techniques for the tested images.

Tested Images	Traditional Polynomial Coding with Quantization Steps of Coefficients are 1,2,2											
	Quant. Res=5		Quant. Res=10		Quant. Res=20		Quant. Res=30		Quant. Res=40		Quant. Res=50	
	CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR
Lena	3.3227	45.0201	3.8523	39.3012	4.2413	34.9135	4.3708	32.6720	4.4329	31.1426	4.4667	30.0366
Rose	3.7186	45.4949	4.1249	40.3562	4.3743	36.3577	4.4461	34.4059	4.4783	33.2660	4.4943	32.5447
Pepper	3.3660	45.4495	3.8397	40.1009	4.2134	35.6955	4.3488	33.3775	4.4162	31.8072	4.4564	30.7622

Clearly from the above table that the performance of the compressing capability varies according to the quantization step (level) of the residual image, where directly affected the quality, but with small change in compression ratio due to the wide range of residual image values and the simplicity of the symbol encoder.

Equations (5-8) suggested by Burget and Das [13], that utilized the standard deviation of the residual image, here the proposed system exploited two alternatively ways to uses the same concept of mid tread seven level quantizer once by adopted the standard deviation of each block independently, and second also using the residual block base multiplied by a factor value, such as:

$$\sigma_{\min} = \sigma_R \times factor \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Table 2-The performance of the proposed techniques for the tested images.

Tested Images	*Proposed System with Quantization Steps of Coefficients are 1,2,2, LHThr=21,HLThr=36,HHThr=32, Using the Seven Midtread Quantization base adopted by Burget & Das that utilized the minimum standard deviation value of residual image*	
	CR	*PSNR*
Lena	8.5556	31.7175
Rose	9.6718	35.5568
Pepper	9.2434	34.1135
Tested Images	*Proposed System with Quantization Steps of Coefficients are 1,2,2, LHThr=21,HLThr=36,HHThr=32, Using the Seven Midtread Quantization base adopted by Burget & Das that utilized the minimum standard deviation value of each block of residual image*	
	CR	*PSNR*
Lena	9.1761	39.9909
Rose	10.9417	41.6514
Pepper	9.7961	40.8763
Tested Images	*Proposed System with Quantization Steps of Coefficients are 1,2,2, LHThr=21,HLThr=36,HHThr=32, Using the Seven Midtread Quantization base adopted by Burget & Das that utilized the minimum standard deviation value of residual image multiplied by factor=0.3*	
	CR	*PSNR*
Lena	11.0123	36.0333
Rose	13.7880	39.2310
Pepper	12.4652	37.4190
Tested Images	*Proposed System with Quantization Steps of Coefficients are 1,2,2, LHThr=21,HLThr=36,HHThr=32, Using the Seven Midtread Quantization base adopted by Burget & Das that utilized the minimum standard deviation value of residual image multiplied by factor=1.5*	
	CR	*PSNR*
Lena	12.3320	35.8790
Rose	15.6931	37.9231
Pepper	13.8634	35.9995

The results showed that the compression ratio improved using the seven level midtread quantization scheme especially, using the residual block base along with preserving high image quality.

4. Conclusions

This paper investigated the utilization of hybrid image compression technique of polynomial coding linear base and multiresolution scheme of discrete wavelet transform (DWT) along with quantization techniques of midtread and soft thresholding. Also this paper enhanced the midtread quantization base using block base and selected factor that implicitly affected the performance trade-off between computation time, quality, and compression ratio.

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