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Bit Plane Slicing, Wavelet and Polynomials Mixing for Image Compression

Rana Talib Al-Timimi

Department Banking and Financial Sciences, College of Management and Economic, Al-Mustansiriyah University, Iraq

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Abstract

This paper introduced a hybrid technique for lossless image compression of natural and medical images; it is based on integrating the bit plane slicing and Wavelet transform along with a mixed polynomial of linear and non linear base. The experiments showed high compression performance with fully grunted reconstruction.

Keywords: Bit Plane Slicing, Wavelet Transform, Lossless Image Compression, Polynomial Prediction.

ضغط الصور بأستخدام طريقة تشريح البت والتحويل المويجي و خليط متعدد الحدود

رنا طالب التميمي

قسم العلوم المالية والمصرفية ، كلية الإدارة والاقتصاد ، الجامعة المستنصرية ، العراق

الخلاصة

في هذا البحث تم تقديم طريقة هجينة لضغط الصورالأعتيادية والطبية بدون خسارة ,حيث اعتمدت الطريقة على الجمع بين تشريح البت والتحويل المويجي ومزيج من التنبوء الخطي واللاخطي متعدد الحدود.اظهرت النتائج نسبة ضغط عالية مع استرجاع مطابق بالكامل للصورة الأصلية .

Introduction

Lossless compression of images is characterized by maintaining the quality of an image and ,therefor, the reconstructed image is the same as the original, but the compression ratio has a small values recorded as less than 10 [1]. This is because of focusing on the coding redundancy and/or inter pixel redundancy.

Researchers in recent years exploit ways to increase the lossless compression system's efficiency either by designing a technique that selects certain blocks and ignores the others or by merging several techniques such as the prediction and wavelet [2-6].

By applying the wavelet transform, the best compression ratio will be attained as compared to the spatial domain [7] where the image is decomposed into four sub bands (LL, HL, LH, and HH sub bands images). This process may be applied several times on the LL sub band image. The approximation sub band (LL) contains all image information; thus, it is considered as the most important part, while the other sub-bands are considered less significant as they contain very little amount of image information [8].

Bit Plane Slicing (BPS) was adopted as a technique combined with the well-known image compression methods by several researchers [9-11]; it is a separation technique used to generate eight binary images (eight layers: layer0 - layer7) according to bit position, where Low Order Layers (LOLs) represented by layers0-layer3 have small significant image details and therefore is ignored, while the High Order Layers (HOLs) (layer4-layer7) contain the most significant image details [12].

*Email: rana_talib@uomustansiriyah.edu.iq

This paper introduces a technique to compress gray images based on determining the wavelet transform, along with a mixed polynomial of first and second order representation, that effectively improved the compression ratio.

Materials and Methods

The main concerns taken in the suggested method are:

Keeping the high order layers and neglecting the low order layers of bit plane slicing effectively reduces the number of bits from 8 to 4 bits, which means an implicit reduction in image information. Integrating the Wavelet Transform with the mixed polynomial coding of linear and non linear approximation model was achieved to compress the image. Figure-1 clearly illustrates the layout of the proposed method.

The proposed hybrid compression system implementation is described in details below.

1-The input: gray scale image (I) of size n*n.

2- Bit-Plane Slicing (BPS) was used to was used to produce eight binary bit plane images form image I, each plane was of size n*n. The higher top order bit planes (4-7) of significant major image were used and the lower order bit planes (0-3) were discarded.

3- The wavelet transform was exploited to produce four quadrants sub bands (LL and detail sub bands LH, HL and HH) each of size n/2×n/2; then we applied the polynomial approximation model on the LL sub-band, such that:

For **bit slicing 7** *non-linear* polynomial prediction was applied on approximation of the sub band LL7 **Otherwise for bit planes 4,5,6** *linear* polynomial prediction was used on approximation of the sub bands LL4.LL5 and LL6.

4- for bit slicing 7:

- the approximated Image $\widetilde{LL}7$ was determined using equation (15).
- the error (residual) was found using equation (16).

5- for bits slicing 4,5,6:

- the approximated Images $\widetilde{LL}4$, $\widetilde{LL}5$ and $\widetilde{LL}6$ were determined using equation (20).
- the errors (residual) $LL4\,\mathrm{Re}\,sd$, $LL5\,\mathrm{Re}\,sd$ and $LL6\,\mathrm{Re}\,sd$ were found using equation (21).

non-linear polynomial prediction [13,14] was applied using the following equations:

$$a_1 = \frac{\sum_{i=0}^{n-1/2}\sum_{j=0}^{n-1/2} \quad j) \times (j - x_c)}{\sum_{i=0}^{n-1/2}\sum_{j=0}^{n-1/2} (j - x_c)^2} \tag{1}$$

$$a_2 = \frac{\sum_{i=0}^{n-1/2}\sum_{j=0}^{n-1/2} LL7(i,j) \times (i - y_c)}{\sum_{i=0}^{n-1/2}\sum_{j=0}^{n-1/2} (i - y_c)^2} \tag{2}$$

$$a_5 = \frac{\sum_{i=0}^{n-1/2}\sum_{j=0}^{n-1/2} LL7(i,j)(j-xc)(i-yc)}{\sum_{i=0}^{n-1/2}\sum_{j=0}^{n-1/2} (j-xc)^2 (i-yc)^2} \tag{3}$$

$$xc \qquad c = \frac{n-1}{2} \tag{4}$$

$$n/2 \times n/2 \tag{5}$$

$$W_2 = \sum_{j=0}^{n-} \quad xc)^2 = \sum_{i=0}^{n-1/2} (i - yc)^2 \tag{6}$$

$$W_3 = \sum_{j=0}^{n-1/2} (j - xc)^4 = \sum_{i=0}^{n-1/2} (i - yc)^4 \quad (7)$$

$$W_4 = \sum_{i=0}^{n-1/2} \sum_{j=0}^{n-1/2} (j - xc)^2 (i - yc)^2 \quad (8)$$

$$V_1 = a_0 W_1 + a_3 W_2 + a_4 W_2 \quad (9)$$

$$V_2 = a_0 W_2 + a_3 W_3 + a_4 W_4 \quad (10)$$

$$V_3 = a_0 W_2 + a_3 W_4 + a_4 W_3 \quad (11)$$

$$a_0 = \frac{\begin{vmatrix} V_1 & W_2 & W_2 \\ V_2 & W_3 & W_4 \\ V_3 & W_4 & W_3 \end{vmatrix}}{\begin{vmatrix} W_1 & W_2 & W_2 \\ W_2 & W_3 & W_4 \\ W_2 & W_4 & W_3 \end{vmatrix}} \quad (12)$$

$$a_3 = \frac{\begin{vmatrix} W_1 & V_1 & W_2 \\ W_2 & V_2 & W_4 \\ W_2 & V_3 & W_3 \end{vmatrix}}{\begin{vmatrix} W_1 & W_2 & W_2 \\ W_2 & W_3 & W_4 \\ W_2 & W_4 & W_3 \end{vmatrix}} \quad (13)$$

$$a_4 = \frac{\begin{vmatrix} W_1 & W_2 & V_1 \\ W_2 & W_3 & V_2 \\ W_2 & W_4 & V_3 \end{vmatrix}}{\begin{vmatrix} W_1 & W_2 & W_2 \\ W_2 & W_3 & W_4 \\ W_2 & W_4 & W_3 \end{vmatrix}} \quad (14)$$

$$L\tilde{L}7 = a0W1 + a1(j - xc) + a2(i - yc) + a3(j - xc)^2 + a4(i - yc)^2 + a5(j - xc).(i - yc) \quad (15)$$

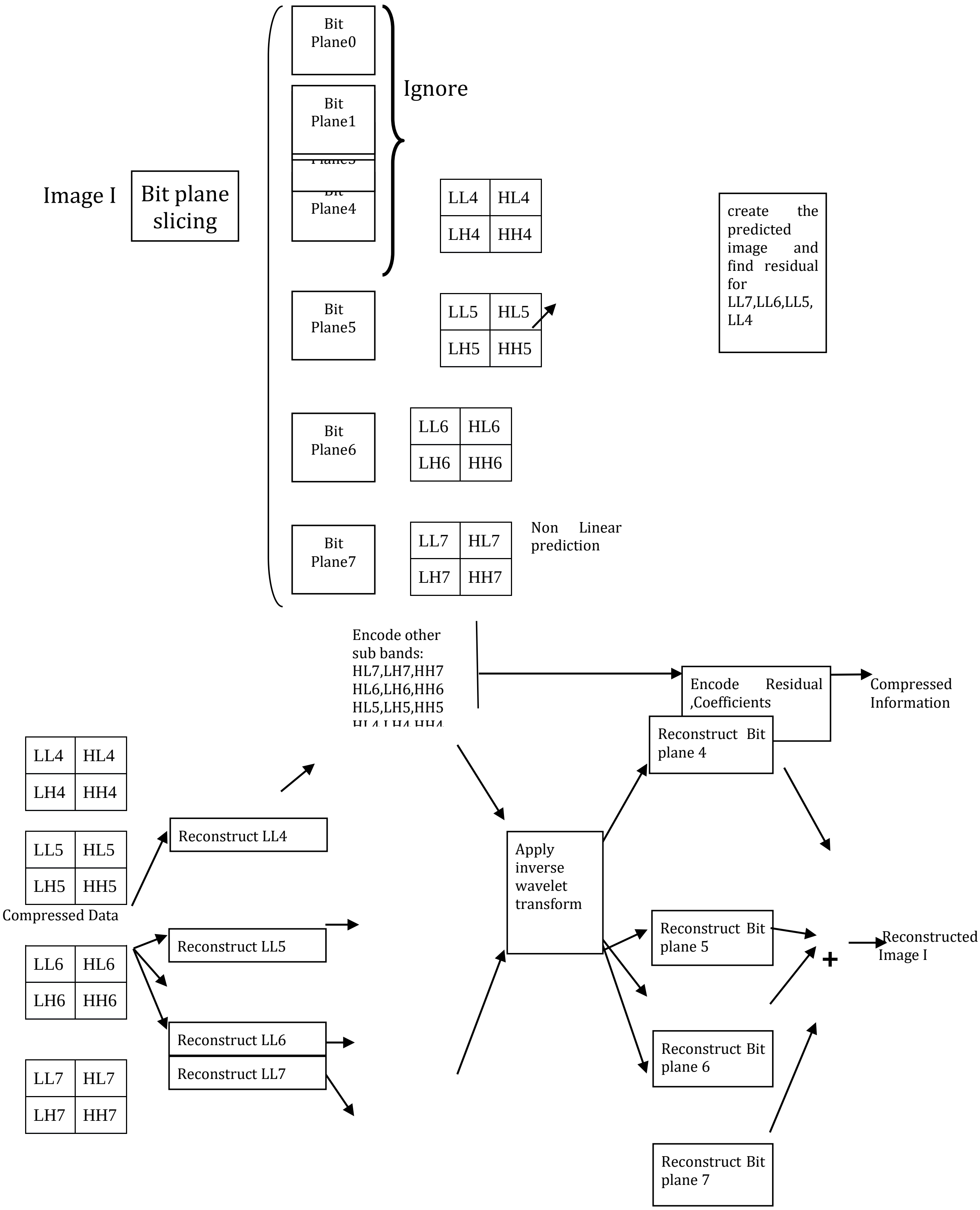


Figure 1-Compression and decompression System Structure

$$LL7\,Resd = L7 - L\tilde{L}7 \tag{16}$$

The linear prediction coefficients were adopted [14,15] using the following equations :

$$a_0 = \frac{1}{n/2 \times n/2} \sum_{i=0}^{n-1/2} \sum_{j=0}^{n-1/2} LL(i,j) \quad (17)$$

$$a_1 = \frac{\sum_{i=0}^{n-1/2} \sum_{j=0}^{n-1/2} LL(i,j) \times (j - x_c)}{\sum_{i=0}^{n-1/2} \sum_{j=0}^{n-1/2} (j - x_c)^2} \quad (18)$$

$$a_2 = \frac{\sum_{i=0}^{n-1/2} \sum_{j=0}^{n-1/2} LL(i,j) \times (i - y_c)}{\sum_{i=0}^{n-1/2} \sum_{j=0}^{n-1/2} (i - y_c)^2} \quad (19)$$

$$L\tilde{L} = a0 + a1(j - x_c) + a2(i - y_c) \quad (20)$$

6-The residual [15, 16, 17] was calculated as follows:

$$LL\, Resd = L - L\tilde{L} \quad (21)$$

7-To reconstruct the original image:
A- LL quadrant 4,5,6 & 7 were reconstructed by adding the residual to the predicted data:

$$LL = L\tilde{L} + LL\, Resd \quad (22)$$

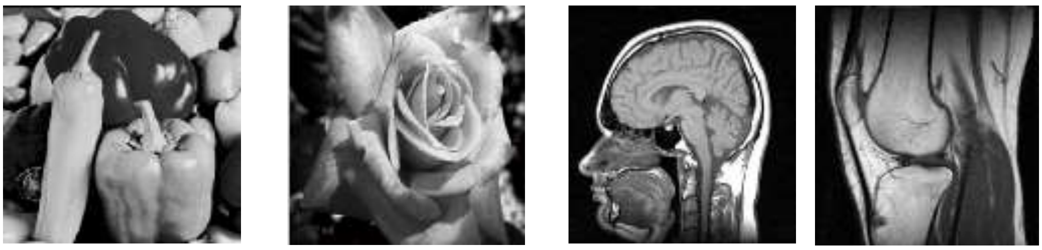
B-the bit plane was reconstructed by using the inverse wavelet transforms.

Results and Discussion

As a lossless compression, the performance measures were based on determining the Compression Ratio (CR) as in equation (23).

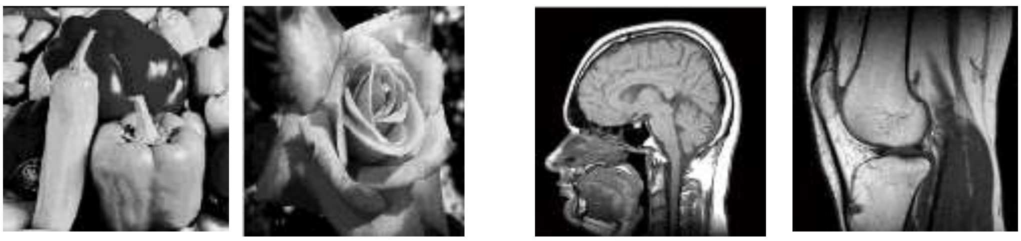
$$\text{Compression Ratio (CR)} = \frac{\text{Size of Original Image}}{\text{Size of Compressed Information}} \quad (23)$$

Two sets of images (natural and medical) were tested to report the performance of the proposed hybrid system (Figure-2). All tested images were of 256 gray levels (8bits/pixel) and of the size 256×256. Figure-3 illustrates the output images after the decompression process, while Figure 4 shows the eight layers, bit planes slicing for the tested input images.



a **B** **c** **d**

Figure 2-The Tested Grayscale Images,(a) Pepper (b) Rose (c) Brain and (d) Knee



a **b** **c** **d**

Figure 3-The Output Images after the Decompression(a) Pepper (b) Rose (c) Brain and (d) Knee

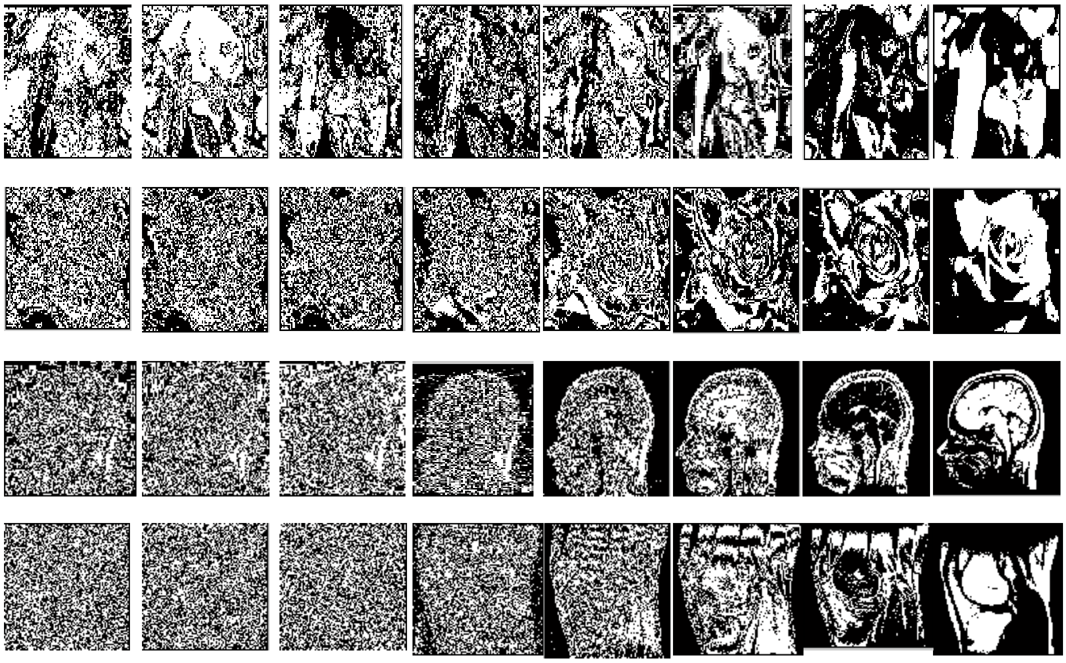


Figure 4-Bit plane slicing of Tested Images from Layer 0 to Layer 7.

Table-1 illustrates the compression performance of the suggested hybrid compression technique using two blocks sizes (4*4 & 8*8).

Tables-(2 and 3) show the compression performance of two compression techniques, the traditional (nonlinear and linear, respectively).

The suggested hybrid lossless system was fast and simple. It was also obvious from the test results reported in Table-1 that the compression ratio was improved as compared with the results of the other methods (listed in Tables-(2 and 3).

Table 1-Performance of the Suggested Technique

		Block size 4*4		**Block size 8*8**	
Test image	**original image size (in bytes)**	**compressed information size (in bytes)**	**Compression Ratio**	**compressed information size (in bytes)**	**Compression Ratio**
Pepper	65536	5878	11.1494	5462	11.9985
Rose	65536	5624	11.6529	5240	12.5069
Brain	65536	5610	11.6820	5208	12.5837
knee	65536	6824	9.6038	5608	11.6862

Table 2-Performance of non linear Traditional Compression System

		Block size 4*4		Block size 8*8	
Test image	**original image size (in bytes)**	**compressed information size (in bytes)**	**Compression Ratio**	**compressed information size (in bytes)**	**Compression Ratio**
Pepper	65536	7738	8.4694	7110	9.2174
Rose	65536	7100	9.2304	5968	10.9812
Brain	65536	7324	8.9481	7310	8.9653
knee	65536	7234	9.0594	6320	10.3696

Table 3-Performance of Linear Traditional Compression System

		Block size 4*4		Block size 8*8	
Test image	**image size (in bytes)**	**compressed information size (in bytes)**	**Compression Ratio**	**compressed information size (in bytes)**	**Compression Ratio**
Pepper	65536	8018	8.1736	77730	8.4781
Rose	65536	7312	8.9628	6434	10.1859
Brain	65536	8528	7.6848	8024	8.1675
knee	65536	6952	9.4269	6436	10.1827

Conclusions

The suggested hybrid technique is characterized by simplicity and efficiency. Combining the bit plane slicing with wavelet transforms leads to saving more storage space and hence affects the compression ratio due to preserving layers (4-7) and ignoring layers (0-3) from the bit plane, ultimately reducing the number of bits from 8 to 4 which implicitly means a reduction in image information. Finally, the compression ratio depended on the approximation of sub band LL block size, such that when the size gets bigger, fewer coefficients are needed, and this will implicitly improves the compression ratio

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