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Selective Bit Plane Coding and Polynomial Model for Image Compression

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***Abstract:** In this paper, a hybrid lossy image compression technique is proposed, based on integrating wavelet transform with polynomial prediction and bit plane slicing. The test results showed highly performance in terms of compression and quality compared to the traditional techniques that utilized the polynomial prediction model only.*

***Keywords:** BPS, HOLs, MSE.*

1. INTRODUCTION

Image compression is an attractive multimedia area to researcher, in which transmission & storage in data bases essential to save time & cuts costs. Today, there are well known international standards like JPEG, GIF used for example in web, even, there's increase needs to deliver other techniques, but most of them still under development like predictive coding and fractal. In general, image compression based on utilizing redundancy that can be grouped into two types, psycho-visual & statistical redundancy. Based on the way of exploiting the redundancy image compression techniques can fall in one of two types lossy or lossless each one has its own characteristics and limitations. Review of various image compression techniques can be found in [1-5]. Prediction of polynomial model of linear based efficient promising techniques achieve high performance [6-10], on the other hand, Bit-Plane Slicing (BPS) is one of the simple popular techniques [11-13]. This paper, propose a simple efficient compression system based on integrate the above two mentioned techniques. The rest of the paper organized as follows, section 2 explains the proposed system in details; the experimental results and discussion is given in section 3.

2. PROPOSED SYSTEM

This section describes the implementation of the proposed compression system that combines Bit-Plane Slicing (BPS) method with the polynomial model; the following steps with Figure (1) illustrated the layout clearly:

Step 1: Load the input grayscale image I of size $N \times N$ with 256 colors (i.e.,8 bits per pixel) that corresponds to original uncompressed image of huge size in byte, usually burdened with redundancy types psycho-visual & statistical (i.e., interpixel & coding).

Step 2: Apply Bit-Plane Slicing (BPS) to slice the image into eight binary images; the techniques simply separate the image into eight layers according to bit position (i.e., $layer_0$, $layer_1$, $layer_2$, $layer_3$, $layer_4$, $layer_5$, $layer_6$ & $layer_7$). According to layers relative importance, the first four layers (i.e., form $layer_0$ to $layer_3$) referred as Low Order Layers (LOLs), while the last four layers referred as High Order Layers (HOLs).

Step 3: Perform implicit reduction or compression of image information resultant from step above by discarding the Low Order Layers (LOLs) and preserving the High Order Layers (HOLs) that effectively reduce the number of bits from 8 bits into 4 bits. In other words, in order to preserving the image quality without visual degradation of image keeps the High Order Layers (HOLs) that implicitly contains the most significant image details and loss or discard the Low Order Layers (LOLs) of small significant on image details.

Step 4: Create selective bit plane image S from the High Order Layers (i.e., $layer_4$, $layer_5$, $layer_6$ & $layer_7$), the idea basically based on selecting an image composed from the high order images depending on image details by partitioning the images into fixed block size $n \times n$ then comparing the four image layers block by block, the block with maximum sum highest details selected.

Step 5: Find difference or residual between the original image I and the selective bit plane image S resultant from the step above.

$D = I - S$…….(1)

Where I original image, S selective residual image composed of High Order Layers (HOLs). The difference image D contains lower information than the original one due to removal of interpixel redundancy.

Step 6: Apply prediction process of polynomial linear base on this residual selective image, which composed of the following steps:

1- Partition image D into fixed non-overlapped blocks of sizes $n \times n$.

2- Estimates polynomial linear model coefficients according to equations (2,3&4) [6].

$$a_0 = \frac{1}{n \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} D(i,j) \text{..........}(2)$$

$$a_1 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} D(i,j) \times (j - x_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (j - x_c)^2} \text{.........}(3)$$

$$a_2 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} D(i,j) \times (i - y_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (i - y_c)^2} \text{.........}(4)$$

Where $D(i,j)$ is the selective bit plane image block of size $n \times n$ and

$$xc = yc = \frac{n-1}{2} \text{.....................}(5)$$

3- Exploit psycho-visual redundancy by quantizing the computed polynomial coefficients using the simple popular uniform scalar quantizer, the quantization step parameters vary according to the coefficients effects, in which a_0 coefficients more quantization level required than the other coefficients. The quantization/dequantization of the coefficients respectively, such as [8]:

$$a_0Quant = round\left(\frac{a_0}{Step_{a0}}\right) \text{.........}(6)$$

$$a_1Quant = round\left(\frac{a_1}{Step_{a1}}\right) \text{.........}(7)$$

$$a_2Quant = round\left(\frac{a_2}{Step_{a2}}\right) \text{.........}(8)$$

$$a_0Dequant = a_0Quantround \times Step_{a0} \text{.........}(9)$$

$$a_1Dequant = a_1Quantround \times Step_{a1} \text{.........}(10)$$

$$a_2Dequant = a_2Quantround \times Step_{a2} \text{.........}(11)$$

Where $Step_{a0}$, $Step_{a1}$ and $Step_{a2}$ the quantization steps of the coefficients of the *Quant*ization and *Dequant*ization process.

4- Create the predicted or approximated image D_{Pred} such as:

$$D_{Pred} = a_0Dequant + a_1Dequant(j - xc) + a_2Dequant(i - yc) \text{..................}(12)$$

5- Find prediction error or residue between difference D image and predicted image D_{Pred} .

$$Res(i,j) = D(i,j) - D_{Pred}(i,j) \text{..................................}(13)$$

At this point, the residue corresponds to decorrelation image, in which the spatial or correlation embedded between pixels removed.

6-Apply quantization process for lossy residue compression to remove the psycho-visual redundancy:

$$ResQuant = round\left(\frac{Res}{Step_{Res}}\right) \text{.........}(14)$$

7- Remove the coding redundancy between the compressed information represented by quantized residue image, coefficients & index of selective bit plane mage by converting into variable length coding using Huffman coding techniques.

8- Reconstruct the decoded or decompressed image, start by using the symbol decoder on compressed information (results of step 7 above); then the dequantizer required for the residue image (see eq. 15); lastly the techniques added the residual with the predicted image (see eq. 12) with the residue.

$$ResDequant = ResQuant \times Step_{Res} \text{.........}(15)$$

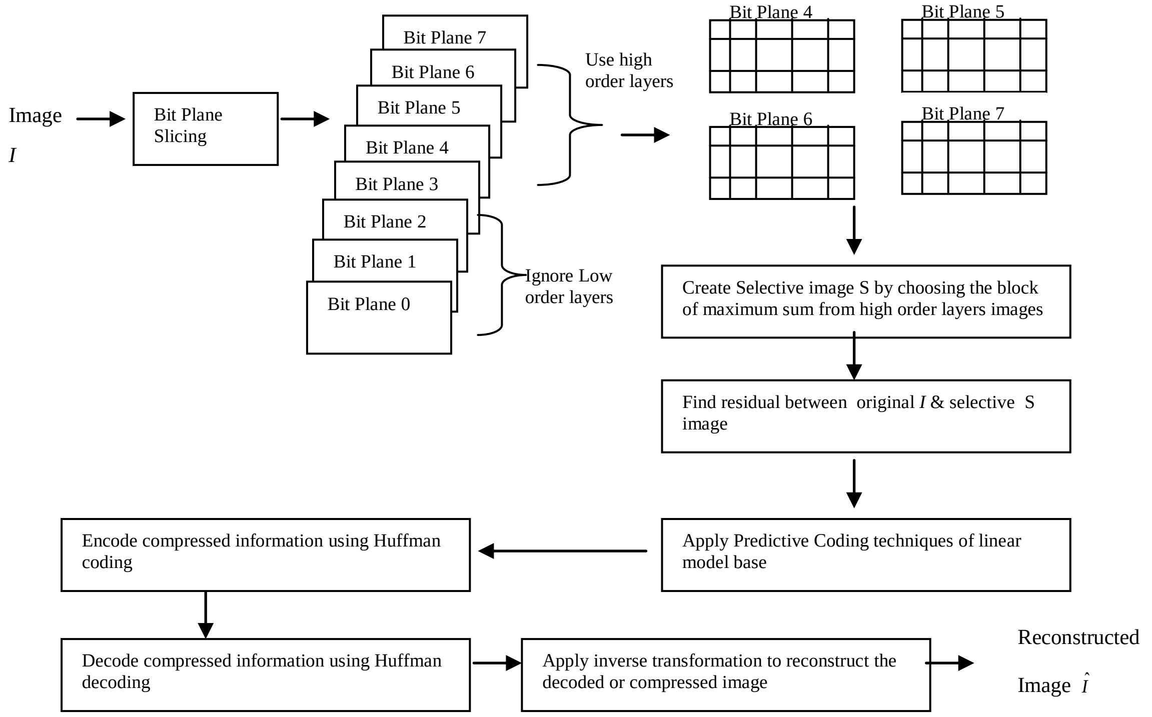

Fig. (1): Proposed System Structure

3. EXPERIMENTS and RESULTS

The performance of the proposed system evaluated and compares it with the traditional linear approximation prediction model, also the well-known standard images (see Figure 2) of block size of 4×4 used with various quantization levels of coefficients and residue image.

The compression ratio (i.e., ratio of the original image size to the compressed size in bytes) adopted to measure the compression efficiency, in addition to the objective fidelity criteria of root mean square error (MSE) (see eq. 16) between original image I and the approximated compressed/decoded image $\hat{I}$.

$$MSE = \frac{1}{N \times N} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [\hat{I}(x,y) - I(x,y)]^2 \quad \text{.......................................(16)}$$

Small MSE values implicitly means the approximated image close to the original image ($\hat{I} \approx I$), and vice versa.

The experimental results of both traditional and proposed techniques showed in table (1). The eight layers of bit plane slicing shown in Figure 3 for the tested images. Clearly the results illustrated that the proposed system achieved highly performance in terms of compression and quality, the compression ratio improved about three times more or less on average due to using the using of the bit plane slicing that already eliminate four bits and also the efficiency of the approximation linear prediction model of lossy based, the quality improved where the MSE strongly reduced compared to the traditional technique due to the using the residual (i.e., difference between original and selective bit plane image) as an alternative way of manipulating with the original image directly. Figure 4 shows the indexed between the high order layers for the four tested images respectively. The performance varies according to image details and the quantization levels utilized.

Lena Girl Paper Camera man

Fig. (2): Tested images of size 256×256, gray scale images.

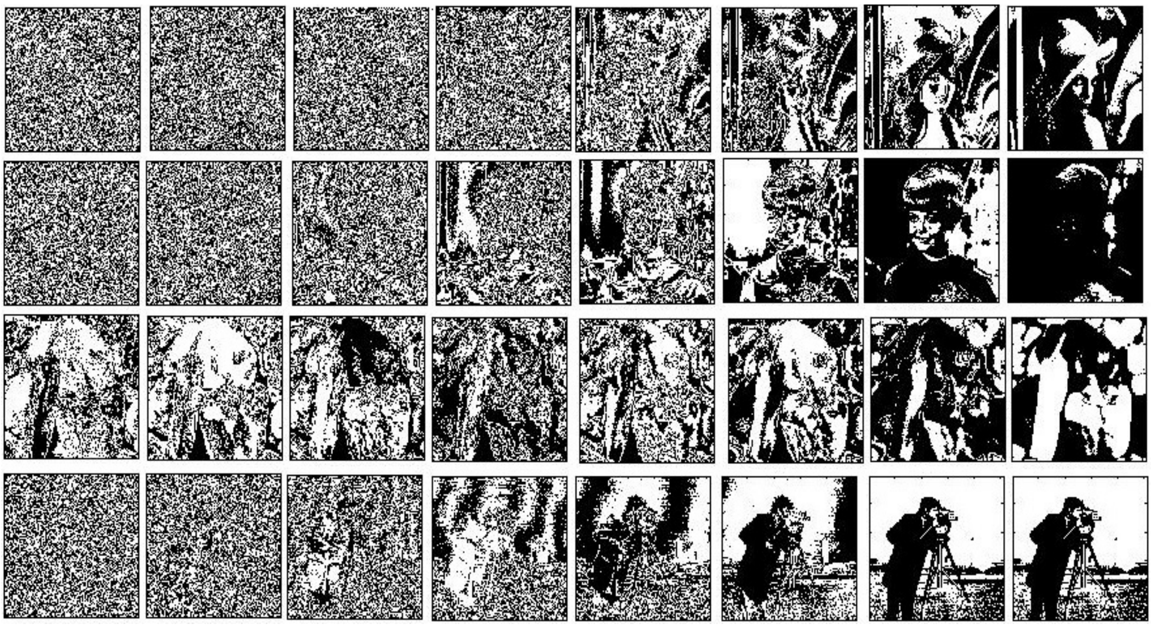

Fig. (3): Bit plane slice of tested images, from $layer_0$ to $layer_7$.

Table (1): Comparison between lossy compression methods for tested images

Tested image	Size in bytes of original image	Quantization coefficients			Quantization Residual	Traditional Techniques.		Proposed Techniques	
		a_0	a_1	a_2		CR	MSE	CR	MSE
Lena	65536	8	4	4	32	5.1120	45.0155	11.9417	14.3153
	65536	8	4	4	64	4.2314	10.3372	9.7524	3.4278
	65536	16	8	4	32	4.9701	29.1485	12.6959	16.2732
	65536	16	8	8	64	4.2446	8.0118	9.6038	3.9722
Girl	65536	8	4	4	32	5.1766	30.1757	15.7010	11.5850
	65536	8	4	4	64	4.3470	6.8919	12.2314	2.7793
	65536	16	8	4	32	5.3727	22.3966	16.5746	9.9342
	65536	16	8	8	64	4.7483	6.7682	11.6695	2.8636
Paper	65536	8	4	4	32	5.1906	73.7787	16.2944	12.8020
	65536	8	4	4	64	4.4765	14.5753	13.8730	3.0751
	65536	16	8	4	32	5.1963	46.5753	18.0540	13.6367
	65536	16	8	8	64	4.6113	17.8864	13.2076	4.6765
Cammera-Man	65536	8	4	4	32	5.0089	67.5031	17.3192	15.2825
	65536	8	4	4	64	4.1759	11.7573	14.2904	3.4267
	65536	16	8	4	32	5.2555	41.2140	19.1850	11.7924
	65536	16	8	8	64	4.6572	15.6781	13.3203	3.4124

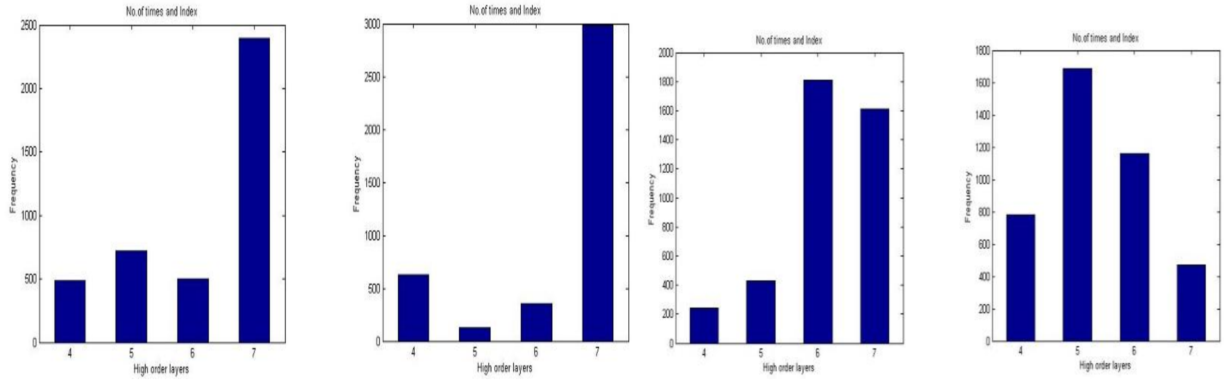

Fig. (4): Indexed of selective high order bit planes of tested images.

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