Polynomial Color Image Compression

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Abstract

In this paper a color polynomial image compression scheme is suggested, it is based on utilizing the color bands of RGB color system solely along with exploiting the linear polynomial coding of variable block sizes according to the correlation embedded between bands. The test results of the suggested method are promising especially in case with mixed symbol encoder techniques compared with different symbol encoder techniques.

Keywords — *Color image compression, polynomial coding, and mixed between symbol encoder techniques*

I. INTRODUCTION

Compression methods are being rapidly developed to compress large data files such as images, where data compression in multimedia applications has lately become more vital [1]. Generally, a compression system represents the essential form of information processing used to manipulate significant information properly, while losing insignificant information, which is called the redundancy [2].

Image compression techniques are categorized into two main types depending on the redundancy removal way, namely lossless and lossy. Lossless types techniques are characterized by their simplicity and no loss of information allowed (the reconstructed identical to the original data), that utilized the statistical redundancy only with low compression rate, such as Huffman coding, Arithmetic coding, Run Length coding and Lempel-Ziv algorithm. While lossy types techniques are characterized by degrade image quality (the original data cannot be reconstructed exactly from the compressed data there is some degradation on image quality) that utilized the psycho-visual redundancy, either solely or combined with statistical redundancy with higher compression rate, such as Vector Quantization, Fractal, JPEG and Block Truncation coding [3].

In general, color images suffer from spectral redundancy (i.e., statistical redundancy) embedded between its bands, in addition to its main redundancy types, where neighbouring bands are not independent but highly correlated. Color images usually decomposed into Red (R), Green (G) and Blue (B) color bands. The only limitation of using this representation that it requires large amount of information, so low compression ratio achieved [4]. Various techniques adopted to overcome the color compression system complexity along with improving efficiency [5-10].

Today, the polynomial coding techniques adopted by researchers to compress image efficiently, based on modeling concept of Taylor series approximation base, for more details see [11-17]. Ghadah et al. (2016) [18], introduced a simple hybrid color compression technique of RGB color system base, that effectively mixed between the hard/soft thresholding techniques of block base and the spatial/frequency domains, where the polynomial coding and the wavelet transform exploited. The results showed the optimizing in the compression ratio along with preserving the image quality by mixing hard and soft thresholding.

In this paper, a traditional color polynomial coding technique of RGB base utilized with variable block sizes that varies according to correlation embedded between color image bands, along with exploits the mixed of symbol encoder techniques. The suggested color compression system discussed in section 2 and the results are given in section 3, followed by the conclusions in section 4.

II. THE PRPOSED SYSTEM

In this suggested system the color image bands compress independently using the traditional linear polynomial coding of variable block sizes that changes according to the amount of correlation embedded between color image bands, also using different symbol encoder techniques in an attempt to mixed between them to increase the compression performance.

The implementation of the proposed system is explained in the following steps, the layout is illustrated in figure (1):

<u>*Step 1*</u>: Load the input uncompressed color image I of BMP format of size $N{\times}N$.

<u>*Step 2 :*</u> Split the I into its bands (I_R, I_G, I_B), each of size $N{\times}N$ of high spectral redundancy, where I_R,I_G,I_B corresponding to R,G and B image bands respectively, then compute the cross correlation between color image bands according to equation below.

$$R(xband, yband) = \frac{\sum_{i=0}^{n-1}[(xbandi - mx)\times(ybandi - my)]}{\sqrt{\sum_{i=0}^{n-1}(xbandi - mx)^2}\sqrt{\sum_{i=0}^{n-1}(ybandi - my)^2}} \text{.......... ....(1)}$$

Where R is a measure of estimating the degree to which two images are correlated, mx and my are the mean of the two images corresponding to $xband$ and *yband* respectively. Here the cross correlation computed between I_R, I_G, then I_R, I_B and I_B, I_G.

Step 3: Apply the polynomial coding techniques directly for each band, using different block sizes, where the technique involves the following sub steps:
1- Partition the image bands non-overlapped blocks, where for highly correlated band *n*×*n* adopted, while for less correlated 2*n*×2*n* and for small one 4*n*×4*n*.

2- Compute the linear polynomial coefficients according to equations (2-4).

$$a_{0bands} = \frac{1}{n \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} I_{bands}\ (i,j)\ \ldots\ldots\ldots(2)$$

$$a_{1bands} = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} I_{bands}\ (i,j) \times (j - X_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (j - {X_c}^2)}\ \ldots\ldots\ldots(3)$$

$$a_{2bands} = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} I_{bands}\ (i,j) \times (j - Y_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (j - {Y_c}^2)}\ \ldots\ldots\ldots(4)$$

Where a_{0bands} coefficient corresponds to the mean (average) of block of sizes (*n*×*n*, 2*n*×2*n*, 4*n*×4*n*) of image bands I_{bands} where $I_{\ bands}$ have three bands of I_R,I_G,I_B. The a_{1bands} and a_{2bands} coefficients represent the ratio of sum pixel multiplied by the distance from the center to the squared distance in *i* and *j* coordinates respectively, and the (*j*-x_c) and (*i*-y_c) corresponds to measure the distance of pixel coordinates to the block center (x_c, y_c) [11].

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

3- Use the scalar uniform quantization/dequantization process for the estimated coefficients with different quantization step of each coefficient of each band.

$$a_{0\,bands}\ Q = round\ (\frac{a_{0\,bands}}{QS_{a\,0\,bands}}) \rightarrow a_{0\,bands}\ D = a_{0\,bands}\ Q \times QS_{a\,0\,bands}\ \ldots\ldots\ldots(\ 6)$$

$$a_{1\,bands}\ Q = round\ (\frac{a_{1\,bands}}{QS_{a\,1\,band}\ s}) \rightarrow a_{1\,bands}\ D = a_{1\,bands}\ Q \times QS_{a\,1\,bands}\ \ldots\ldots\ldots\ (7)$$

$$a_{2\,bands}\ Q = round\ (\frac{a_{2\,bands}}{QS_{a\,2\,bands}}) \rightarrow a_{2\,bands}\ D = a_{2\,bands}\ Q \times QS_{a\,2\,bands}\ \ldots\ldots\ldots(\ 8)$$

Where $a_{0\,bands}\ Q, a_{1\,bands}\ Q, a_{2\,bands}\ Q$ are the polynomial quantized values, $QS_{a\,0\,bands}, QS_{a\,1\,bands}, QS_{a\,2\,bands}$ are the quantization steps of the polynomial coefficients, and $a_{0\,bands}\ D, a_{bands\ 1} D, a_{2\,bands}\ D$ are polynomial dequantized values.

dequantized values.
4- Create the predicted images $\tilde{I}_{bands}$ using the dequantized polynomial coefficients of each encoded block representation:

$$\tilde{I}_{bands} = a_{0\,bands}\ D + a_{1bands}\ D(j - x_c) + a_{2\,bands}\ D(i - y_c) \ldots\ldots\ldots\ \ldots\ldots\ldots\ \ldots(9)$$

5- Find the residuals as the difference between the original image bands and the predicted bands created from step above.

$$Res_{bands}(i,j) = I_{bands}(i,j) - \tilde{I}_{bands}(i,j) \ldots\ldots\ldots\ldots(10)$$

6- Quantize/dequantize the residual images uniformly with different quantization steps.

$$Res_{bands}Q = round\left(\frac{Res_{bands}}{Qs_{Res}}\right) \rightarrow Res_{bands}D = Res_{bands}Q \times Qs_{Res}\ \ldots(11)$$

Step 4: Encode the compressed information of quantized coefficients and residuals, using different symbol encoder techniques and mixed between them.
Step 5: Reconstruct the decoded compressed image $\hat{I}(i,j)$, by first rebuild each band separately by adding the residual dequantized image along with the predicted image, followed by adding the reconstructed bands to reconstruct the compressed or decoded image.

$$\hat{I}_{bands}(i,j) = \tilde{I}_{bands}(i,j) + \mathrm{ResD}_{bands}(i,j) \ldots\ldots\ldots\ldots(12)$$

III. EXPERIMENTAL AND RESULTS

Three standard color images are selected for testing the proposed compression system (see figure 2 for an overview). Lena is characterized by a wide variety of image details, making it a complex highly detailed picture, while girl small or less variations in image detail, having large smooth areas with low detail. Medical lies somewhere between the two. All the images are a square of the same size, 256×256, and color of (24 bits/pixel). To evaluate the performance of the proposed compression system two objective measures utilized, the compression ratio used (*CR*) which is the ratio between the original image size and the compressed size (equation 13), and the peak signal to noise ratio (*PSNR*) (equation 14), where a large *PSNR* value implicitly means high image quality and close to the original image and vice versa.

$$\text{Compression Ratio} = \frac{\text{size of the original image}}{\text{size of compressed image information}} \ldots\ldots\ldots\ldots(\ 13\ )$$

$$PSNR\ (I, \hat{I}) = 10\ \log\ 10\ \frac{(MaximumGra\quad yLevel\ )^2}{MSE} \ldots\ldots\ldots(\ \ 14\ )$$

$$MSE\ (I, \hat{I}) = \frac{1}{N \times N} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \left[\hat{I}(i,j) - I(i,j)\right]^2 \ldots\ldots\ldots\ \ldots\ldots(15)$$

Table 1 illustrates the cross correlation embedded between the color bands, identify the spectral redundancy related to Red/Green, Red/Blue, and Green/Blue bands, where in most cases the Green band adopted as a highly correlated band of block size *n*×*n*, either the Red and Blue corresponding to less correlated and small correlated of sizes 2*n*×2*n* *and* 4*n*×4*n* respectively

Table 2 shows the system performance for the three test images using different block size (2×2, 4×4, 8×8), with quantization steps of coefficient equals to 1,2,2 and wide range of residual values from 5-70, along with different symbol encoder techniques of Huffman coding , Huffman coding with Run Length coding , Huffman coding with LZW and with mixed between them all (Huffman coding with LZW and Run Length Coding).

There are a number of highlight issues need to be mentioned according to the above result:

1. Obviously, the quantization step of residual image affected both the compression ratio (*CR)* and the quality in terms of *PSNR*.
2. The tradeoff inverse relation between *CR* and quality is clearly shown, where for low *CR* attains the high *PNSR* value, and vice versa.
3. The lower compression ratio achieved using the Huffman technique due the simplify of simple encoder, which by incorporating more technique higher compression attained especially by mixing the probability based along with dictionary based techniques.
4. Obviously, the compression ratio and *PNSR* are directly affected by the image's characteristics or details, where for highly detailed images less compression ratio and high *PNSR* archived compared to images with small and moderate details.

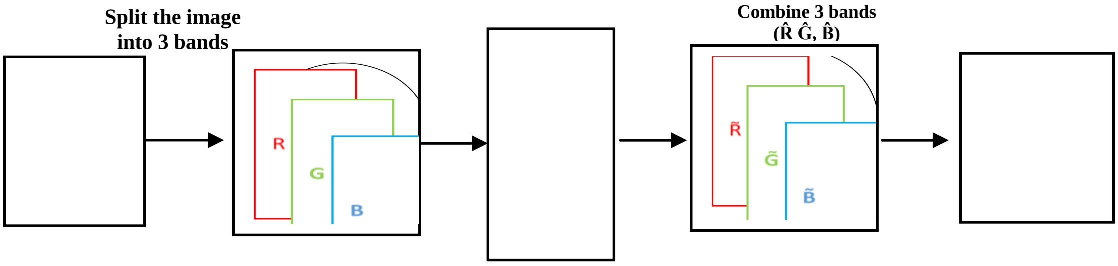

Fig 1: The Proposed System Structure.


a
b
c

Fig 2: The test image a -'Lena ' b- Girl' ' c-Medical'

Table 1: The Cross Correlation of Tested Images Which Utilized as a Statistical Guide to the Image Correlation, or the Redundancy Present Within the Image Features or Contents.

Tested Images	Cross Correlation between Color image bands of spectral redundancy		
	$I_R I_G$	$I_R I_B$	$I_G I_B$
Lena	0.8895	0.7089	0.9222
Girl	0.7712	0.6819	0.9126
Medical Image	1.0000	1.0000	1.0000

Table 2: The Color Polynomial Linear Compression Performance of Compression Ratio and PSNR for Tested Images.

Tested Image	Block Sizes of 2x2,4x4,8x8 and Quantization Coefficients of 1,2,2								
	Q. Level residual.	RGB Poly. with Huffman		RGB Poly. with Huffman + Rlc		RGB Poly. with Huffman + LZW		RGB Poly. with mixed (Huffman + LZW + Rlc)	
		PNSR	CR	PNSR	CR	PNSR	CR	PNSR	CR
Lena	**5**	44.4809	3.097	44.4809	4.9218	44.4809	4.234	44.4809	8.5866
	10	39.5057	3.3608	39.5057	5.6235	39.5057	4.8645	39.5057	11.6481
	20	35.3212	3.517	35.3212	6.0749	35.3212	5.4752	35.3212	15.8927
	50	31.4732	3.606	31.4732	6.3455	31.4732	6.0792	31.4732	22.3342
	70	31.3027	3.6312	31.3027	6.4238	31.3027	6.2306	31.3027	24.5239
Girl	**5**	43.8321	3.1621	43.8321	4.9211	43.8321	4.0763	43.8321	7.5595
	10	38.7068	3.4442	38.7068	5.6399	38.7068	4.8081	38.7068	10.5324
	20	34.739	3.6186	6.1233	6.1233	34.739	5.6306	34.739	15.4883
	50	31.809	3.6997	31.809	6.359	31.809	6.3859	31.809	22.9575
	70	31.6759	3.709	31.6759	6.3867	31.6759	6.5271	31.6759	24.8934
Medical image	**5**	48.7119	3.9248	48.7119	5.5305	43.8321	4.0763	48.7119	11.914
	10	43.1148	4.2005	43.1148	6.0941	38.7068	4.8081	43.1148	15.077
	20	38.226	4.4387	38.226	6.6087	34.739	5.6306	38.226	20.167
	50	33.3389	4.6237	33.3389	7.0272	31.809	6.3859	33.3389	29.948
	70	32.8671	4.6539	32.8671	7.0972	31.6759	6.5271	32.8671	34.33

III.CONCLUSIONS

The test results clearly showed the efficiency of the of the proposed system where correlation measure adopted to determine the block size of the polynomial coding of RGB color system, also showed the superiority of the mixed symbol encoder techniques

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