Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 5.258

IJCSMC, Vol. 5, Issue. 7, July 2016, pg.375 – 381

Hybrid Color Image Compression of Hard & Soft Mixed Thresholding Techniques

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Abstract

In this paper, a simple hybrid color compression technique is introduced 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.

Keywords: Color image compression, wavelet transform, polynomial coding, hard and soft thresholding.

Introduction

Today, as a result of the immense revolution in computer and communication, image compression becomes an important research area essentially concerned with storage capacity and transmission bandwidth [1]. In general, image compression techniques fall into two categories: lossless and lossy depending on the redundancy type exploited. For the former where no information loss this also called information preserving or error free techniques in which the compressed image identical to the original, that used for certain critical applications in fields such as the military, space programmes, medicine, meteorology or remote-sensing, based on exploited the statistical redundancy only that characterized with low compression ratio, such as Huffman coding, Arithmetic coding, Run Length coding and Lempel-Ziv algorithm. While the latter where some information is lost, in which compressed image approximated to the original one, applied to our daily visual media applications, including TV, video film, the internet, based on exploited the psycho-visual redundancy, either alone or combined with statistical redundancy that characterized with higher compression ratio, such as vector quantization, fractal and block truncation coding. Reviews of lossless and lossy techniques can be found in [2-5].

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 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 [6]. Various techniques can be utilized to compress color images can be found in [7-14].

Currently, a number of researchers have exploited the polynomial technique to compress images [13-19] that basically identify the coefficients and residual.

In this paper, a hybrid mixed color image compression technique is suggested that implies two integrated parts: the first combines between the discrete wavelet transform and polynomial coding as a hybrid system of spatial and transform coding bases. The second investigates the mixed between thresholding techniques of hard and soft base.

The rest of the paper is organized as follows, section 2 contains comprehensive clarification of the proposed system; the results of the proposed system is given in section 3.

The Propose Hybrid Mixed Compression System

The steps bellow explains the proposed system clearly, and the system structure is depicted with Figure (1).

Step 1: Load the input uncompressed color image *I* of *BMP* format of size $N \times N$.

Step 2: Separate the color image into its bands (R, G, B), each of size $N \times N$.

Step 3: Apply the polynomial coding techniques of linear base [14], for the red image (I_R), that simply involves the following sub steps [10]:

1- Partition the red image (I_R) into non-overlapped blocks of fixed size $n \times n$, such as (4×4) or (8×8).

2- Compute the linear polynomial coefficients according to equations (1-3).

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

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

$$a_2 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} I_R(i,j) \times (i - y_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (i - y_c)^2} \quad (3)$$

Where a_0 coefficient corresponds to the mean (average) of block of size ($n \times n$) of red image I_R. The a_1 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, 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) [6].

$$xc = yc = \frac{n-1}{2} \quad (4)$$

3- Quantize/dequantize the estimated coefficients above, using the scalar uniform quantization process with different quantization step of each coefficient.

$$a_0Q = round\left(\frac{a_0}{QS_{a0}}\right) \rightarrow a_0D = a_0Q \times QS_{a0} \quad (5)$$

$$a_1Q = round\left(\frac{a_1}{QS_{a1}}\right) \rightarrow a_1D = a_1Q \times QS_{a1} \quad (6)$$

$$a_2Q = round\left(\frac{a_2}{QS_{a2}}\right) \rightarrow a_2D = a_2Q \times QS_{a2} \quad (7)$$

Where a_0Q, a_1Q, a_2Q are the polynomial quantized values, $QS_{a0}, QS_{a1}, QS_{a2}$ are the quantization steps of the polynomial coefficients, and a_0D, a_1D, a_2D are polynomial dequantized values.

4- Create the predicted image value $\tilde{I}_R$ using the dequantized polynomial coefficients of each encoded block representation:

$$\tilde{I}_R = a_0D + a_1D(j - x_c) + a_2D(i - y_c) \quad (8)$$

5- Find the residual or prediction error as the difference between the original I_R and the predicted one $\tilde{I}_R$.

$$\mathrm{Res}_R(i,j) = I_R(i,j) - \tilde{I}_R(i,j) \quad (9)$$

6- Use the wavelet transform of resultant residual image from the step above, where the residual image is decomposed into approximation and detail sub bands ($\mathrm{Res}R_{LL}$, ResR_{LH}, ResR_{HL} and ResR_{HH}) each of size (*N/2×N/2*).

7- Quantize the approximation and detail sub bands differently according to its importance, where for the approximation subband (i.e., $\mathrm{Res}R_{LL}$) the scalar uniform quantizer /dequantizer adopted as in equation (10). While for the detail's sub bands (i.e., ResR_{LH}, ResR_{HL} and ResR_{HH}), partition the detail's subband into nonoverlapping blocks of fixed size *n×n*, and performs the soft thresholding (see equations 11-13). For more detail about soft thresholding see [13]&[20].

$$\mathrm{Res}R_{LL}Q = round\left(\frac{\mathrm{Res}R_{LL}}{QS_{\mathrm{Res}R_{LL}}}\right) \rightarrow \mathrm{Res}R_{LL}D = \mathrm{Res}R_{LL}Q \times QS_{\mathrm{Res}R_{LL}} \quad (10)$$

$$\mathrm{Res}R_{LH}Q = \begin{cases} Sign(\mathrm{Res}R_{LH})(|\mathrm{Res}R_{LH}| - ThresoldRLH) & if\ |\mathrm{Res}R_{LH}| > ThresoldRLH \\ 0 & else \end{cases} \quad (11)$$

$$\mathrm{Res}R_{HL}Q = \begin{cases} Sign(\mathrm{Res}R_{HL})(|\mathrm{Res}R_{HL}| - ThresoldRHL) & if\ |\mathrm{Res}R_{HL}| > ThresoldRHL \\ 0 & else \end{cases} \quad (12)$$

$$\mathrm{Res}R_{HH}Q = \begin{cases} Sign(\mathrm{Res}R_{HH})(|\mathrm{Res}R_{HH}| - ThresoldRHH) & if\ |\mathrm{Res}R_{HH}| > ThresoldRHH \\ 0 & else \end{cases} \quad (13)$$

Step 4: Use the wavelet transform for the two images green and blue I_G and I_B respectively, where each decomposed into four quadrants of approximation and detail sub-bands of size (*N/2×N/2*). For approximation sub bands correspond to G_{LL} *and* B_{LL}, perform the uniform scalar quantizer/dequantizer such as:

$$G_{LL}Q = round\left(\frac{G_{LL}}{QS_{G_{LL}}}\right) \rightarrow G_{LL}D = G_{LL}Q \times QS_{G_{LL}} \quad (14)$$

$$B_{LL}Q = round\left(\frac{B_{LL}}{QS_{B_{LL}}}\right) \rightarrow B_{LL}D = B_{LL}Q \times QS_{B_{LL}} \quad (15)$$

While for detail's sub bands (G_{LH}, G_{HL}, G_{HH}, B_{LH}, B_{HL} and B_{HH}) the hard thresholding technique of block base adopted that implies partition each image subband into nonoverlapping blocks of fixed size *n×n* followed by performing the hard thresholding. For more detail about hard thresholding see [19].

$$G_{LH}Q = \begin{cases} G_{LH} & if\ |G_{LH}| > ThresoldGLH \\ 0 & else \end{cases} \quad (16) \qquad G_{HL}Q = \begin{cases} G_{HL} & if\ |G_{HL}| > ThresoldGHL \\ 0 & else \end{cases} \quad (17)$$

$$G_{HH}Q = \begin{cases} G_{HH} & if\ |G_{HH}| > ThresoldGHH \\ 0 & else \end{cases} \quad (18) \qquad B_{LH}Q = \begin{cases} B_{LH} & if\ |B_{LH}| > ThresoldBLH \\ 0 & else \end{cases} \quad (19)$$

$$B_{HL}Q = \begin{cases} B_{HL} & if\ |B_{HL}| > ThresoldBHL \\ 0 & else \end{cases} \quad (20) \qquad B_{HH}Q = \begin{cases} B_{HH} & if\ |B_{HH}| > ThresoldBHH \\ 0 & else \end{cases} \quad (21)$$

Step 5: Encode the compressed information of quantized coefficients, quantized sub-bands and quantized quadrants residual using the Lempel-Ziv coding technique.

Step 6: Reconstruct the decoded image $\hat{I}(i,j)$, by firstly applying the inverse wavelet transform of each band, also the red image reconstructed according to equation (22), finally all the bands combined to reconstruct the compressed or decoded image.

$$\hat{I}_R(i,j) = \tilde{I}_R(i,j) + \mathrm{Res}D_R(i,j) \quad (22)$$

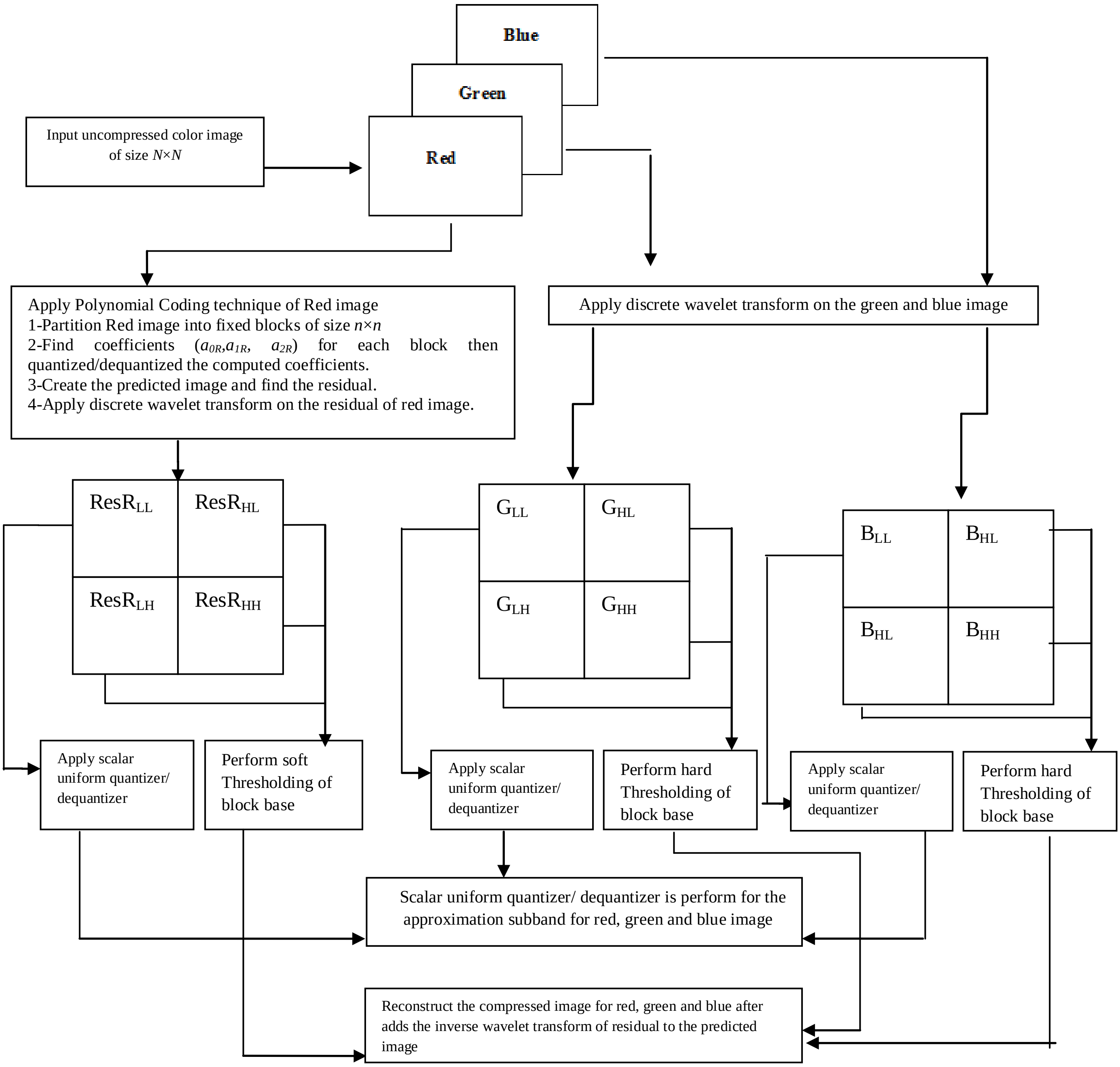

Figure 1- The proposed system structure.

RESULTS AND DISCUSSION

For testing the proposed system performance; two standard images used (see Figure 2), where both the color images of size 256×256, also the block sizes of (*4×4*) is adopted. The quantization coefficients of polynomial technique of red band was selected to be 1,2,2 for a_0, a_1 and a_2 respectively. Also the quantization level of approximation detail subband (Low Low) was selected to be between 5 and 60.

The compression ratio, which is the ratio of the original image size to the compressed size is computed, along with the Peak -Signal-to Noise- Ratio (*PSNR*) between the original image *I* and the decoded image $\hat{I}$ was utilized as a fidelity or degradation measure.

$$PSNR(dB) = 10 \log_{10}\left[\frac{(\max imumgray \ scale \ of \ image)^2}{MSE}\right] \quad ......(23)$$

$$MSE = \frac{1}{N \times N} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} [\hat{I}(x,y) - I(x,y)]^2 \quad ......(24)$$

a b

Figure 2- Overview of the tested images (a) Lena image and (b) Girl image, all images of size 256×256 color images.

The results are shown in table (1) summarizes the compression ratio, PSNR and quantization levels used for the two tested images.

It is clear that the quantization level of approximation band of three bands, along with threshold values of hard and soft techniques of details sub bands of R,G,B affected the performance of the suggested technique in terms of compression ratio and PSNR, where small values means small compression ratio and high PSNR, and vice versa. Also the results illustrates the efficient mixed between hybrid technique of spatial and frequency domain along with hard and soft thresholding of block base.

Figure (3) showed the compressed tested images using 1,2,2 quantization steps of coefficients for the red image and the wavelet transform for the quantization step of residual red image then quantization step of the approximation subband (R_{LL}) was selected to be between 5 and 60 and for the details sub bands of soft thresholding, while for green &blue images using wavelet transform then quantization step of the approximation subband (G_{LL}, B_{LL}) was selected to be between 5 and 60 and for details sub bands of hard thresholding.

Table - 1 Comparison performance of hybrid mixed proposed technique.

Tested Image	Block Size of 4x4 and Quantization Coefficients of 1,2,2			Block Size of 4x4 and Quantization Coefficients of 1,2,2		
	Mixing Hard &Soft Thresholding with details subband R_{HL} G_{HL} B_{HL}= 40, R_{LH} G_{LH} B_{LH}= 60, R_{HH} G_{HH} B_{HH}= 80			Mixing Hard &Soft Thresholding with details subband R_{HL} G_{HL} B_{HL}= 60, R_{LH} G_{LH} B_{LH}= 80, R_{HH} G_{HH} B_{HH}= 100		
	R_{LL} G_{LL} B_{LL}	CR	PSNR	R_{LL} G_{LL} B_{LL}	CR	PSNR
Lena	5	5. 3457	29. 8639	5	5. 7308	29. 6073
	20	7. 5872	29. 7357	20	8. 3874	29. 4826
	40	8. 9837	29. 3691	40	10. 1276	29. 1489
	60	9. 7587	28. 9343	60	11. 1235	28. 7490
Girl	5	6. 1354	31. 9495	5	6. 3613	31. 7590
	20	9. 2539	31. 7150	20	9. 7776	31. 5338
	40	11.4015	31. 1079	40	12. 2071	30. 9551
	60	12.6770	30. 3692	60	13. 6809	30. 2457

Figure 3- The compressed images using the Mixing of Hard & Soft Thresholding techniques.

Mixing Hard &Soft Thresholding with details subband of R_{HL} G_{HL} B_{HL}= 40, R_{LH} G_{LH} B_{LH}= 60, R_{HH} G_{HH} B_{HH}= 80

a- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 5 and Quantization Coefficients = 1,2,2.
b- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 20 and Quantization Coefficients = 1,2,2.
c- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 40 and Quantization Coefficients = 1,2,2.
d- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 60 and Quantization Coefficients = 1,2,2.

Mixing Hard &Soft Thresholding with details subband of R_{HL} G_{HL} B_{HL}= 60, R_{LH} G_{LH} B_{LH}= 80, R_{HH} G_{HH} B_{HH}= 100

e- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 5 and Quantization Coefficients = 1,2,2.
f- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 20 and Quantization Coefficients = 1,2,2.
g- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 40 and Quantization Coefficients = 1,2,2.
h- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 60 and Quantization Coefficients = 1,2,2.

Conclusions

The hybrid mixed technique of polynomial coding, wavelet transform and hard and soft thresholding techniques produce high compression ratio with trade off quality, also the thresholding base of block utilized instead of quadrant base.

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