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HYBRID MIXED COLOR IMAGE COMPRESSION

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ABSTRACT
In this paper, a hybrid color image compression is introduced, it is based on combination between spatial and frequency domains of interpolated base along with mixing of different quantization techniques. The test results indicate that the suggested method can lead to promising performance.

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

1. INTRODUCTION

Today, compression plays an important role in the transmission and storage media. The main aim of image compression is to represent an image in the fewest number of bits without losing the essential information content within an original image data [1]. In general, 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. Review on various lossless and lossy techniques can be found in [2-7].

Color images usually decomposed into Red (R), Green (G) and Blue (B) color bands that are highly correlated [8], so that it may contains a lot of data redundancy(s)and requires a large amount of information that affected storage space and transmission rate, thus data compression become an urgent requirement [6]. More details for color image compression techniques see [9-15].

Currently, a number of researchers have exploited the polynomial technique to compress images due to its simplicity, symmetry of encoder and decoder and high compression rates can provide where no need to extra information to be used, just identify the coefficients and find residual [14-20].

In this paper, a hybrid mixed interpolated color image compression technique is suggested that integrates the combination between discrete wavelet transform and polynomial coding, along with the mixing 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 for the proposed system and the conclusions, is given in sections 3 and 4, respectively.

2. THE PROPOSED 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 $N \times N$, that unfortunately quite overburdened with spectral redundancy.

Step 2: Separate the color image into its bands (I_R, I_G, I_B), each of size $N \times N$ corresponds to high resolution images of high correlation.

Step 3: Apply the interpolation techniques of nearest neighbor base of two layers of I_G and I_B images, namely create the medium and low resolution images I_{G1}, I_{B1} and I_{G2}, I_{B2} each of size ($N/2 \times N/2$) and ($N/4 \times N/4$) respectively.

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Step 4: Use the polynomial coding techniques of linear base [15], for the compressing red image (I_R) and the interpolated shrinked images of low resolution base from the step above, I_{G2}, I_{B2} that simply involves the following sub steps [11]:

i. Partition the images (I_R, I_{G2}, I_{B2}) into non-overlapped blocks of fixed size $n\times n$, such as (4×4) or (8×8).

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

$$a_{0bands}=\frac{1}{n\times n}\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}I_{bands}(i,j)\text{............}(1)\qquad a_{1bands}=\frac{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}I_{bands}(i,j)\times(j-x_c)}{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(j-x_c)^2}\text{..........}(2)\qquad a_{2bands}=\frac{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}I_{bands}(i,j)\times(i-y_c)}{\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(i-y_c)^2}\text{............}(3)$$

Where a_0 $_{bands}$, coefficient corresponds to the mean (average) of block of size ($n\times n$) of input image bands I_{bands} where I_{bands} have three bands (red, green, blue). The a_1 $_{bands}$ and a_2 $_{bands}$ 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) [10]&[14].

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

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

$$a_{0bandsQ}=round\left(\frac{a_{0bands}}{QS_{a0bands}}\right)\rightarrow a_{0bandsD}=a_{0bandsQ}\times QS_{a0bands}\text{.......}(5)$$

$$a_{1bandsQ}=round\left(\frac{a_{1bands}}{QS_{a1Rbands}}\right)\rightarrow a_{1bandsD}=a_{1bandsQ}\times QS_{a1bands}\text{.........}(6)$$

$$a_{2bandsQ}=round\left(\frac{a_{2bands}}{QS_{a2bands}}\right)\rightarrow a_{2bandsD}=a_{2bandsQ}\times QS_{a2bands}\text{.......}(7)$$

Where $a_{0bandsQ},a_{1bandsQ},a_{2bandsQ}$ of image I that have three bands (red, green, blue) are the polynomial quantized values, $QS_{a0bands},QS_{a1bands},QS_{a2bands}$ are the quantization steps of the polynomial coefficients, and $a_{0bandsD},a_{1bandsD},a_{2bandsD}$ are polynomial dequantized values.

iv. Create the predicted images $\tilde{I}$ of image I where I have three bands (red, green, blue) using the dequantized polynomial coefficients of each encoded block representation:

$$\tilde{I}bands=a_{0bandsD}+a_{1bandsD}(j-x_c)+a_{2bandsD}(i-y_c)\text{.....................}(8)$$

v. Construct the medium layer of the two interpolated lower images using the enlarging process of nearest neighbor interpolation, such as:

a- Build the enlarged image $In_{Med}[I_{G1}]$ and In_{Med} $[I_{B1}]$ of medium size resolution 128×128 from the predicted images $\tilde{I}_{B2}$ and $\tilde{I}_{G2}$ of size 64×64.

b- Find the first residual image as difference between the original shrinked images of medium resolution $I_{G1}$and I_{B1} and the interpolated one from the step above see [21].

$$eG_1=I_{G1}-In_{Med}[I_{G1}]\text{.....................}(9)$$

$$eB_1=I_{B1}-In_{Med}[I_{B1}]\text{.....................}(10)$$

vi. Compute the prediction error as the difference between the original red image I_R and the predicted red one $\tilde{I}_R$.

$$\mathrm{Re}\,s_R(i,j)=I_R(i,j)-\tilde{I}_R(i,j)\text{..........................}(11)$$

vii. Use the discrete wavelet transform of resultant prediction error & difference images from the steps above (5b and 6), where the residual images is decomposed into approximation and detail sub bands Res_R, eG_1 and eB_1 each of size ($N/2\times N/2$).

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viii. Quantize the approximation and detail sub bands differently according to its importance, where for the approximation subband (i.e., Res_{RLL}, eG_{1LL}, eB_{1LL}) the scalar uniform quantizer /dequantizer adopted as in equation (12). While for the detail's sub bands (i.e., Res_{RLH}, Res_{RHL}, Res_{RHH}, eG_{1LH}, eG_{1HL}, eG_{1HH}, eB_{1LH}, eB_{1HL} and eB_{1HH}), partition the detail's subband into nonoverlapping blocks of fixed size $n \times n$, and performs the soft & hard thresholding (see equations 13&14). For more detail about the thresholding techniques see [16,12] & [22].

$$\mathrm{Re}\,sbands_{LL}^{Q} = round\left(\frac{\mathrm{Re}\,sbands_{LL}}{QS_{\mathrm{Re}\,sbands_{LL}}}\right) \rightarrow \mathrm{Re}\,sbands_{LL}^{D} = \mathrm{Re}\,sbands_{LL}^{Q} \times QS_{\mathrm{Re}\,sbands_{LL}} \ldots\ldots\ldots\ldots(12)$$

$$\mathrm{Re}\,sbands_{LH}^{Q} = \begin{cases} Sign(\mathrm{Re}\,sbands_{LH})(|\mathrm{Re}\,sbands_{LH}| - ThresoldbandsLH \; if \; |\mathrm{Re}\,sbands_{LH}| \rangle ThresoldRLH \\ 0 \; else \end{cases} \ldots\ldots\ldots(13)$$

$$eG_{1}bandsLH^{Q} = \begin{cases} eG_{1}bandsLH & if \; |eG_{1}bands_{LH}| \rangle ThresoldeG_{1}bandsLH \\ 0 & else \end{cases} \ldots\ldots\ldots(14)$$

ix. Apply the inverse wavelet transform to reconstruct the red image, the medium green & blue images I_{G1} and I_{B1} constructed as a sum of interpolated one $In_{Med}[I_{G1}]$ and In_{Med} $[I_{B1}]$ along with the dequantized the first residual, such as:

$$IG_1 = In_{Med}[IG1] + eG_1D \ldots\ldots\ldots(15)$$

$$IB_1 = In_{Med}[IB1] + eB_1D \ldots\ldots\ldots(16)$$

Step 5: Build the high resolution images for green and blue bands, by applying the same steps in 4 above using the medium constructed layers, that start by creating the enlarged image $In_{Hgt}[I_G]$ and In_{Hgt} $[I_B]$ of high size resolution *256×256* from the approximated image I_{G1} and I_{B1} of size 128×128. Then find the second differences between the original images of high resolution for the green and blue I_G, I_B and the interpolated

$$eG_0 = I_G - In_{Hgt}[IG1] \ldots\ldots\ldots(17)$$

$$eB_0 = I_B - In_{Hgt}[IB1] \ldots\ldots\ldots(18)$$

The wavelet transform used for the differences images above, also the same quantization process is applied for the approximation and details sub bands using the hard thresholding techniques.

$$eG_0bandsLL^{Q} = round\left(\frac{eG_0bands_{LL}}{QS_{eG_0\,bands_{LL}}}\right) \rightarrow eG_0 \; bands_{LL}^{D} = eG_0 \; bands_{LL}^{Q} \times QS_{eG_0bands_{LL}} \ldots\ldots\ldots(19)$$

$$eG_0bandsLH^{Q} = \begin{cases} eG_0bandsLH & if \; |eG_0bandsLH| \rangle ThresoldeG_0bandsLH \\ 0 & else \end{cases} \ldots\ldots\ldots(20)$$

Step 6: Encode the compressed information of quantized coefficients, quantized sub-bands and quantized quadrants residual using the Lempel-Ziv coding technique.

Step 7: Reconstruct the color decoded image $\hat{I}(i,j)$, by firstly applying the inverse wavelet transform of each band, also the red image reconstructed according to equation (21), finally all the bands combined to reconstruct the compressed or decoded image according to equations below:

$$\hat{I}_R(i,j) = \tilde{I}_R(i,j) + \mathrm{Re}\,sD_R(i,j) \ldots\ldots\ldots (21)$$

$$\hat{I}G(i,j) = In_{Hgt}[IG] + eG_0D \ldots\ldots\ldots(22)$$

$$\hat{I}B(i,j) = In_{Hgt}[IB] + eB_0D \ldots\ldots\ldots(23)$$

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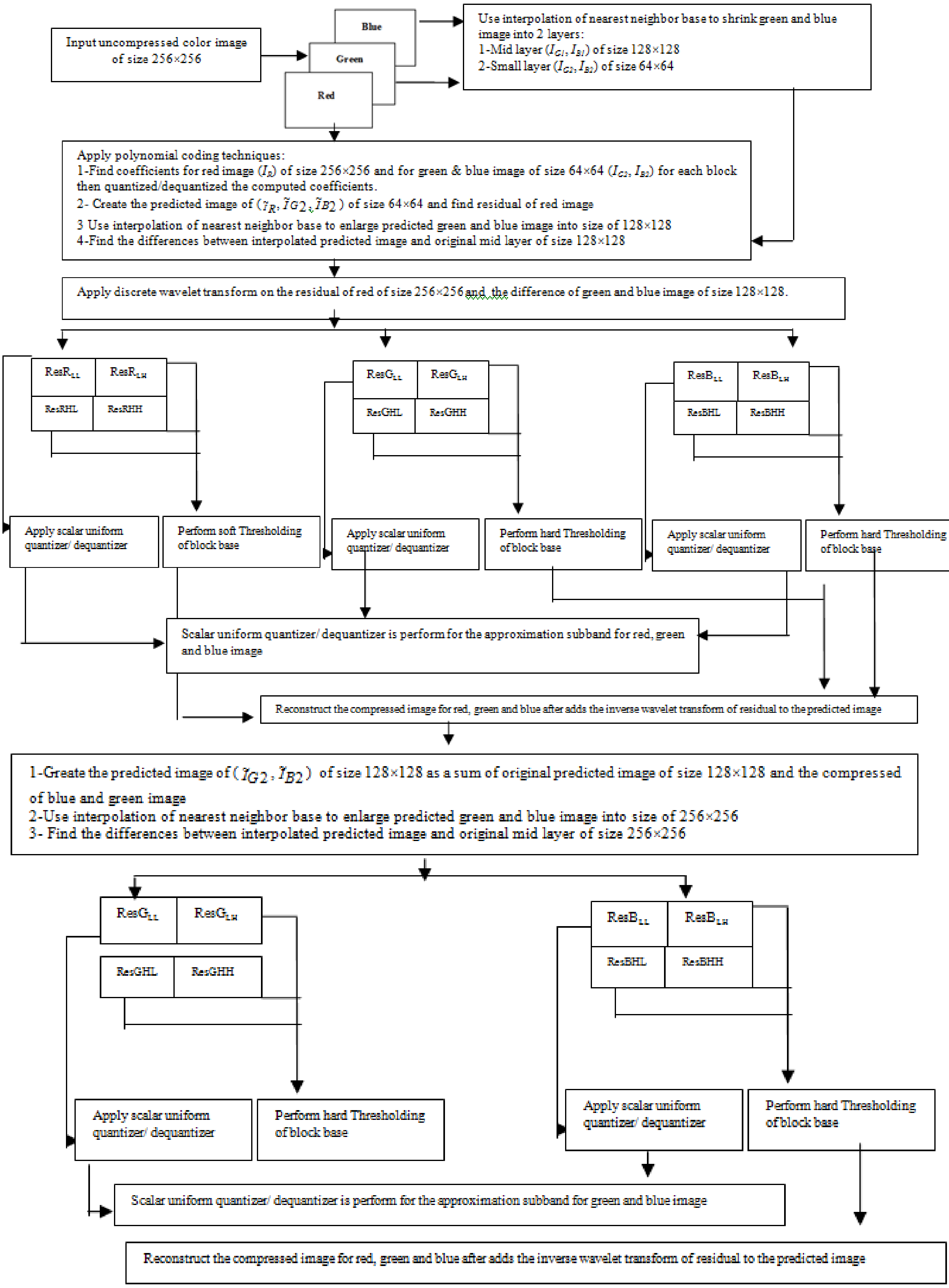

Figure 1- The proposed system structure.

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3. RESULTS AND DISCUSSION

For testing the proposed system performance; three standard color images of size 256×256 adopted (see Figure 2), the block sizes of (*4×4*) is utilized. The quantization coefficients of polynomial technique of red band and for interpolated shrinked images of low resolution for green & blue image of size 64×64 was selected to be 1,2,2 for (a_0, a_1, a_2) of *I* image. Also the quantization level of approximation detail subband (*Low Low*) was selected to be between 2 and 70. While for the detail's sub bands (*Low High, High Low, High High*) performs the soft & hard thresholding as shown in table (1).

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.

$$PSNR(dB) = 10 \log_{10}[\frac{(\max imumgray\ scale\ of\ image)^2}{MSE}] \ldots\ldots\ldots(24)$$

$$MSE = \frac{1}{N \times N} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} [\hat{I}(i,j) - I(i,j)]^2 \ldots\ldots\ldots(25)$$

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

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

It is clear that the quantization level of approximation band of red image and the interpolation technique for the green & blue image 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.

The results also showed that the amount of compression, namely compression ratio is directly affected by the image characteristics or details, where in Lena and Baboon there is great variation of complex details that imply low compression ratio compared to small variation of low details image of girl image.
It is obvious that the interpolation technique aims to decorrelate the image spectral redundancy of color image bands. Lastly, the utilization of discrete wavelet transforms leads to improve the compression ratio and quality.

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 (*RLL*) was selected to be between 5 and 70 and for the details sub bands of soft thresholding, while for green &blue images using interpolation technique then wavelet transform then quantization step of the approximation subband (*GLL*, *BLL*) was selected to be between 5 and 70 and for details sub bands of hard thresholding. The quantization step and the thresholding value affected both quality and compression ratio (CR), where for small quantization steps values low compression ratio achieved with high image quality, while for large quantization steps values high compression ratio achieved with low image quality.

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Table - 1 Comparison performance of interpolation with hard & soft thresholding 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		
	Interpolation with Hard &Soft Thresholding and interpolated technique with details subband R_{LH}=20 G_{LH}=20 B_{LH}= 20, R_{HL}=40 G_{HL}=40 B_{HL}= 40, R_{HH}=60 G_{HH}=60 B_{HH}= 60			Interpolation with Hard &Soft Thresholding and interpolated technique with details subband R_{LH}=40 G_{LH}=40 B_{LH}= 40, R_{HL}=60 G_{HL}=60 B_{HL}= 60, R_{HH}=80 G_{HH}=80 B_{HH}= 80		
	R_{LL} G_{LL} B_{LL}	CR	PSNR	R_{LL} G_{LL} B_{LL}	CR	PSNR
Lena	2	4. 6316	30. 4212	2	5.3693	29.8816
	10	5. 7293	30.3755	10	6.9002	29.8423
	70	7. 4155	29.2204	70	9.5127	28.8722
Girl	2	5. 7032	32. 5432	2	6.5020	31.9842
	10	7. 4259	32. 4599	10	8.8570	31.9127
	70	10.2304	30.7594	70	13.2245	30.4439
Baboon	2	2.7498	26.4306	2	3.2914	25.9665
	10	3.1324	26.4217	10	3.8525	25.9595
	70	3.6797	26.0574	70	4.7141	25.6815

The proposed techniques utilized the hybrid mixed of interpolated base between color image bands according to bands importance, the results shown in this paper are promising in terms of the and quality that would be increased by incorporation the color transformation techniques.

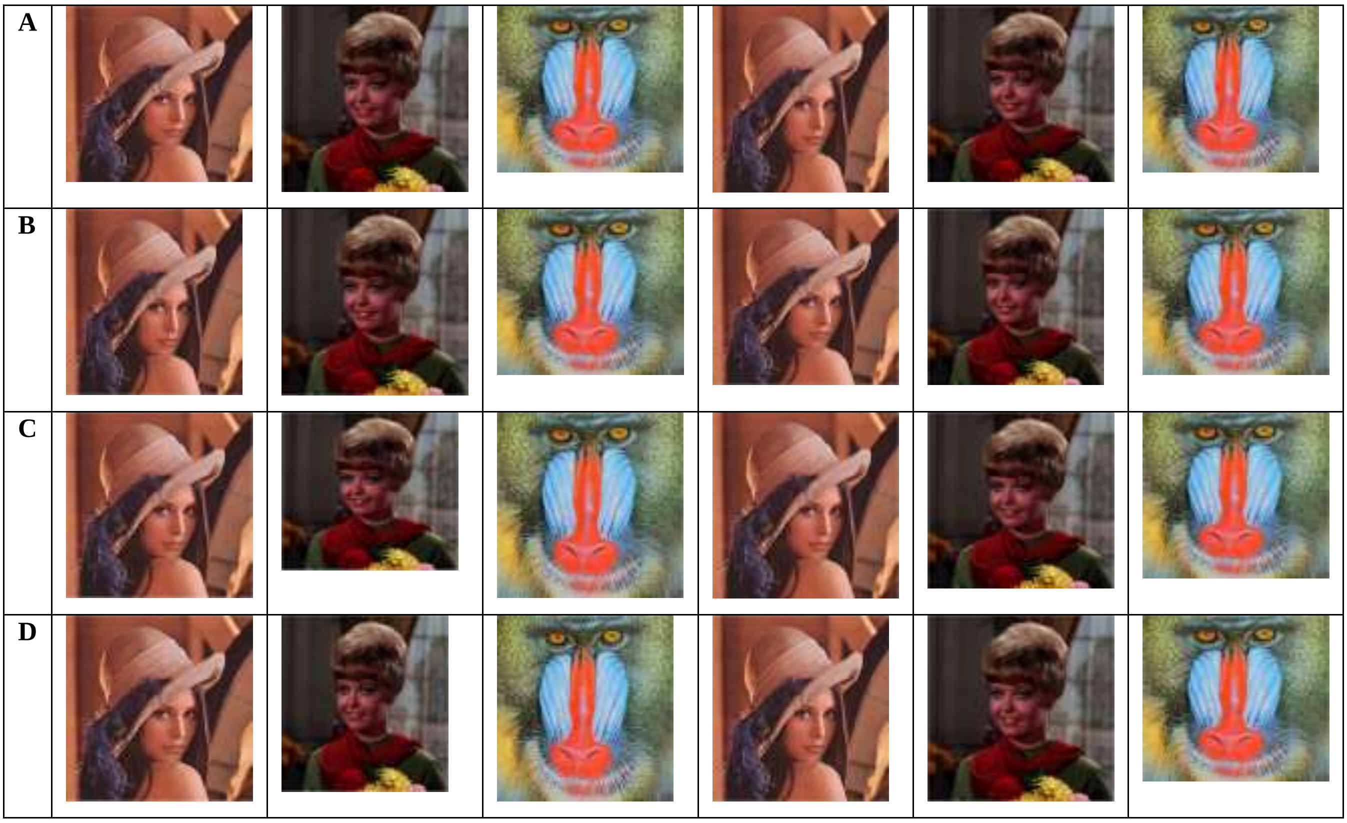

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Figure 3- The compressed images using the Interpolation with Hard & Soft Thresholding techniques.

Interpolation with Hard & Soft Thresholding with details subband of R_{LH}=20 G_{LH}=20 B_{LH}= 20, R_{HL}=40 G_{HL}=40 B_{HL}= 40, R_{HH}=60 G_{HH}=60 B_{HH}= 60

a- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 2 and Quantization Coefficients = 1,2,2.
b- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 10 and Quantization Coefficients = 1,2,2.
c- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 30 and Quantization Coefficients = 1,2,2.
d- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 50 and Quantization Coefficients = 1,2,2.
e- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 70 and Quantization Coefficients = 1,2,2.

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

f- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 2 and Quantization Coefficients = 1,2,2.
g- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 10 and Quantization Coefficients = 1,2,2.
h- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 30 and Quantization Coefficients = 1,2,2.
i- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 50 and Quantization Coefficients = 1,2,2.
j- Approximation Subband (R_{LL} G_{LL} B_{LL}) with Quantization Residual = 70 and Quantization Coefficients = 1,2,2.

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