Adaptive Color Image Compression Using ADJPEG and ISUQ of Hierarchical Decomposition Scheme

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***Abstract*— This paper introduced a lossy color compression system of transform coding (TC) based of discrete wavelet transform (DWT), discrete cosine transform (DCT) and quantization schemes to achieve high compression ratio (CR) with preserving quality. The proposed compression system comprises the following steps, firstly, separating the image into source/non source color bands, then quantizing the source band uniformity, followed by decomposing an image by a three-level DWT and applying huffman coding to the approximation sub band, and compressed the details sub bands of each level by iterative scalar uniform quantization (ISUQ), while the non-source bands apply adaptive developed JPEG (ADJPEG) is utilized with the minimize matrix size algorithm (MMSA) and two integer keys base to reduce AC coefficients effectively. For testing the performance of the suggested compression system, three standard images of size (256×256) pixels adopted. The suggested technique showed superior performance in terms of reconstructed (decoded) image quality and CR, where the CR is between 28-32 with a peak signal-to-noise ratio (PSNR) value between 39-42 dB and the CR of JPEG is between 13-16 with a PSNR value between 33-37 dB.**

***Index Terms*— Image compression, Discrete cosine transform, Discrete wavelet transform, Matrix minimization search algorithm, JPEG, Iterative scalar uniform quantization.**

I. INTRODUCTION

Today, with rapidly evolving technology of digital devices (i.e., computers, mobiles, tablets) and applications (i.e., social media, electronic-learning, and instant messaging), more than 2.5 billion people are active online [1]. The digital color image is intensively used due to its power to convey (change) moods and feelings that lead to make decision, which is the heart of many indispensable technologies such as digital television, cinema, distance learning, cameras, security, marketing, videophones, video conferencing, healthcare, and electronic government (*E-G*) applications [2-3].

Image data compression generally based on utilizing image data redundancy(s) efficiently of statistical and /or psychovisual bases, which implicitly implies lossless and lossy techniques respectively [4-7]. The former image compression techniques of lossless (identical) base also referred to as information-preserving (error free), of low compression performance, due to exploiting the inter-pixel (spatial) and coding redundancies, by utilizing techniques lossless predictive coding, and symbol encoder either of entropy base (i.e., Huffman coding, Arithmetic coding) or probability base (Lempel-Ziv algorithm) [8-12]. While the latter image compression techniques of lossy (approximation) base, of high compression performance, due to exploiting the psychovisual redundancy with/without the statistical redundancy(s), by exploiting techniques such as, Fractal, block truncation coding (*BTC*), Absolute *BTC*, joint photographic experts group (*JPEG*), and joint photographic experts group-2000 (*JP2*) [13-16].

Color images are unfortunately overburden with redundancies (spectral redundancy) embedded between color correlated bands that leads to low compression performance [4, 17].

This paper is concerned with an investigation of hybrid lossy color image compression techniques, using the *DWT* decomposition of Haar base, with *ISUQ* for source band along with *ADJPEG* with *MMSA* for non-source bands. The paper is organized as follows: Section 2 reviews the relevant related works, section 3 discusses the methodology of the suggested system in detail, and the following sections are concerned with the experimental results, conclusions.

II. RELATED WORK

Compression techniques is the core of multimedia, in spite of utilizing standard effective techniques, but the need of adaptive and new techniques still required, this section implies relating works of color image compression techniques, MMSA and JPEG.

Ghadah et al. 2016 [18] a lossy hybrid mixed-color RGB image compression. The R color band was compressed using a hybrid system of spatial and TC bases that combined a one-level of Haar DWT with 2-D linear polynomial coding, where the residual part utilizing a scalar uniform quantizer for approximation sub band and soft thresholding for detail sub bands. For the other color bands (G, B bands), that compressed using a scalar quantizer for the approximation sub band and hard thresholding for the detail sub bands of one level of Haar

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DWT. The tested results evaluated using two standard natural color images of size (256×256) pixels, where the CR between 5 to 12 with PSNR values between 29 dB to 31 dB. Ali and Loay 2017 [19] introduced a lossy color image compression of the YUV color transformation model that utilized a bi-orthogonal wavelet transform to decompose each color sub band, separately. Then, encode the approximation (LL) sub band using DCT, whereas the details sub bands are coded using scalar quantization. Also, the quadtree coding process was applied to the outcomes of the DCT and quantization processes. Finally, applying adaptive shift coding as a high order entropy encoder to remove the remaining statistical redundancy and achieve efficiency in the compression process. The tested results utilized two standard natural color images of sizes (256×256) pixels, where the CR between 9 to 36 on average, with PSNR values between 25 dB to 31 dB. Yusra et al. 2019 [20] suggested a lossy hybrid color compression system of YUV color transformation model which based on DWT and hybrid coding algorithm, for each color band the multiresolution decomposition along with utilizing an adaptive quantization scheme that selecting quantization steps according to the wavelet bands which used small quantization step for the approximation sub band (LL), whereas larger quantization step for the details sub bands (HL, LH, HH). Lastly, encoded approximation sub band using the Huffman coding and the detailed sub bands using set partitioning in hierarchical trees (SPIHT). The tested results utilized six standard square/ non square natural color images of sizes (512×512/1280×720) pixels, where the CR between 4 to 13 on average, with PSNR values between 34 dB to 40 dB. Zainab and Loay 2020 [21] presented an image compression system that relies on the transform (DCT or biorthogonal wavelet transform (tap9/7)) and LZW compression technology. TC is used to separate the color sub band once the system has tested the color images, then encode the image using quantization and LZW algorithm. The tested results of the compression demonstrate good efficiency in increasing the compression rate while maintaining the fidelity level at a desirable level. The tested results utilized six standard natural color images of sizes (256×256) pixels, where the CR between 12 to 20 with PSNR values between 32.0083 dB to 32.1462 dB. Bushra and Loay 2021[22], exploited the combination of lossless and lossy image compression techniques to compress natural color images effectively using YUV color transformation, along with least significant value (LSV) and most significant value (MSV) decomposition, where the MSV is compressed lossless technique and the LSV with a lossy technique. The lossless MSV encoder is a mixture based on bit plan slicing (BPS) that separates the positive most values (PMV) from the negative most values (NMV), along differential pulse code modulation (DPCM) of block (3×3), lastly, an adaptive quadtree and an adaptive shift encoder exploited. While the lossy LSV encoder utilized the DCT transform after separating into blocks, then performed quantization to eliminate the insignificant values, followed by the insulation window that moved the DCT coefficients from the north-left quarter of the block to the buffer to increase the CR along with the zigzag arrangement and shift encoder. The tested results utilized two standard natural color images of sizes (256×256) pixels, where the CR between 6 to 17 with PSNR values between 28 dB to 30 dB. Samara and Ghadah 2023 [23] introduced a new lossy color compression of YCbCr base, that mixed between adaptive lossy 1-D polynomial coding, along MMSA of compress by four to one value (C421), and double scalar uniform quantization system (DSUQS), where the CR is between 21 to 27, with PSNR values between 36 dB to 38 dB.

On the other hand, MMSA introduced by Mohammed in 2012 which simply represented the three data values losslessly into a single floating-point value using randomly generated weighted values (keys) between [0-1][2] including Mohammed 2012 [24], suggested an algorithm for an image compression which based on one level DWT decomposition of Daubechies base of ignored the details sub bands followed by applying DCT of approximation sub band of block sizes (2×2) then the DCT coefficients exploring for compressed DC values using the quantization followed by run length coding (RLC), whereas the AC values coded using the MMSA of three keys (weights), along with minimum and maximum values of each column as header-information that was utilized to reconstruct values identically. The tested results are evaluated on three grayscale standard images Lena (500×500) pixel, X-ray (500×522) pixel and Girl (595×774) pixel, For Lena image the CR between 3.7 to 11.13 with PSNR values between 31.5 dB to 33.5 dB of decode average time from 2 sec to 53.9 sec. While for X-ray the CR between 5.21 to 16.71with PSNR values between 29.6 dB to 30 dB of decode average time from 2.3 sec to 151 sec. Lastly for the Girl image the CR between 3.25 to 8.05 with PSNR values between 30.6 dB to 31.9 dB of decode average time from 7.8 sec to 333 sec. Mohammed and Marcos 2017 [25] exploited the same principle for image compression that is based on DCT along with a high-frequency minimization encoding algorithm, that starts by divide the image into blocks of size n×n followed by applying the DCT and the quantization process. Then, split the quantized DCT coefficients into DC and AC components, DC component use the predictive coding (PC) or differential operator for encoding values, while AC components are converted into a 1-D array and saved into an AC-matrix, which is split into zero and non-zero (NZ) data and then the zero data is eliminated by the matrix minimization method, followed by applying a high-frequency minimization encoding algorithm to the NZ data that produces a minimized array used to replace each of the three values from the AC-coefficients by a single floating-point value, which leads to reduce the matrix size and increases compression ratio. Finally, the arithmetic coding is used to encoding values efficiently. The tested results adopted three natural color images of size (1280×1024) pixels, the compressed image size between 5.1 to 14, RMSE values between 2.4 to 5.3.

Finally, JPEG is a well-known sophisticated standard image compression techniques based on utilizing the DCT of TC base effectively to remove the spatial (interpixel) redundancy embedded within the image [16, 26], Enas 2018 [27] proposed a lossy compression system based on an RGB base and color space conversion of YCbCr, where each band is divided into n×n block sizes along the utilization of 1-D DCT, followed by the adaptive scalar quantization of the DCT coefficients, and finally the zigzag adopted with an entropy shift encoder for AC and DC coefficients. The tested results were evaluated using four color standard images of natural base of size (256×256) pixels, the CR for RGB base between 3 to 12, and PSNR values

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between 26 dB to 33 dB, while for the YCbCr base, the CR between 5 to 17, and PSNR values between 27 dB to 36 dB. Abdullah et al. 2020 [16], enhanced JPEG algorithm performance to compress the grayscale and color images by exploiting the fast DCT, with quantization factor (QF), and eliminating/neglecting zero of AC's insignificant values. The suggested system was tested using four images of natural base of size (256×256) pixels, the CR ranging from 3 to 17, and PSNR values between 36 dB to 40 dB. mind that cannot improve the quality after submission.

III. THE PROPOSED SYSTEM

The proposed system is a lossy color system that combines between of transform coding base which implies *DWT* decomposition, *ADJPEG* of 2 lossless values base *MMSA*, along iterative uniform scalar quantizer that clearly shown in Fig. 1.

Step 1: Load the input uncompressed color *RGB* square image *I* (i.e., *N×N×3*) of *BMP* format.

Step 2: Convert *I* into color transformation model of *YCbCr* base.

Step 3: For *Y* source band, apply *DWT* of Haar hierarchical base with an *ISUQ* for compressed *MSV*, where the encoding process is composed of the steps discussed below [28].

a. Quantize the source (*Y*) color band uniformly using uniform scalar quantization.

b. Apply multi-scheme decomposition of three layers Haar *DWT*, where *I* decomposed into approximation sub band (LL_3) and details sub bands (LH_1, HL_1, HH_1, LH_2, HL_2, HH_2, LH_3, HL_3, HH_3) hierarchally, of sizes (*N/2×N/2*), (*N/4×N/4*) and (*N/8×N/8*) respectively.

c. Encoding the approximation sub band (LL_3) using Huffman coding method.

d. Use *ISUQ* to compress the $I_{Sr\ \text{details}}$ that is composed of the following steps:

1. Converting each of $I_{Sr\ \text{details}}$ of detail sub band of the three levels from a *2-D* array into a *1-D* vector.

2. Preform the *ISUQ* based on iteration and the reminder of each detail sub band values of the three levels, using the sub steps below, also illustrated in Fig. 2:
   i. Make the value of number of division (iteration) and reminder (position) be zero.
   ii. Determine position of zero value(s) (*Pzero*) to exclude it from $I_{Sr\ \text{details}}$

$$P_{zero} = I_{Sr\ details} = 0 \tag{1}$$

   iii. Divided the rest of $I_{Sr\ \text{details}}$ of detail sub band by the division value (Div) base.
   iv. Increase the iteration value by one.
   v. Determine the $I_{Sr\ \text{details}}$ value(s) between specific accuracy range

$$P_{ValAcc} = Accuracy\ range_{low} < |I_{Sr\ details}| \geq Accuracy\ range_{high} \tag{2}$$

   vi. The number of division is corresponding the iteration value

$$No\_of\_Div = iteration \tag{3}$$

   vii. The steps from (i-vii) are repeated iteratively until the values of the $I_{Sr\ \text{details}}$ exceed the accuracy range
   viii. Compute the reminder value

$$Reminer = floor(Rem \times No\_of\_Digits) \tag{4}$$

Rem corresponds to the precision matrix of floating-point values, *No_of_Digits* refers to the decimal number after the point and *Reminder* is the reminder values of the details sub bands of the three levels.

3. Encoding the compressed information that implies reminder values, iteration (number of division) losslessly using the Lempel-Ziv coding method and Huffman coding.

Step 4: The non-source band (C_b and C_r) compression method using *ADJPEG* that exploited the *MMSA* to reduce AC coefficients is explained in the following steps [28]:

i. Use one of the non-source color image band I_{nSr} of size $N \times N$.

ii. Performing the normalization process, which is an essential pre-processing step, in which the normalizing parameter for each image is determined by utilizing the mean of values as in Eq. (5):

$$NorFactor = mean(I_{nSr}) \tag{5}$$

Where NorFactor is normalization factor, mean (I_{nSr}) is the mean value of non-source color band.

Eq. (6) perform normalization process by subtracting half of the normalization factor value from each pixel.

$$Nor_{nSr} = I_{nSr} - ceil(NorFactor/2) \tag{6}$$

Where Nor_{nSr} is normalized non-source band image.

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iii. Partitioning (segmentation): split the Nor_{nSr} image into fixed-sized segments of non-overlapping regions (blocks) of size (*8×8*).

iv. Apply the transformation process: convert each segmented block individually from the spatial domain to the frequency domain using the *DCT* base coding technique.

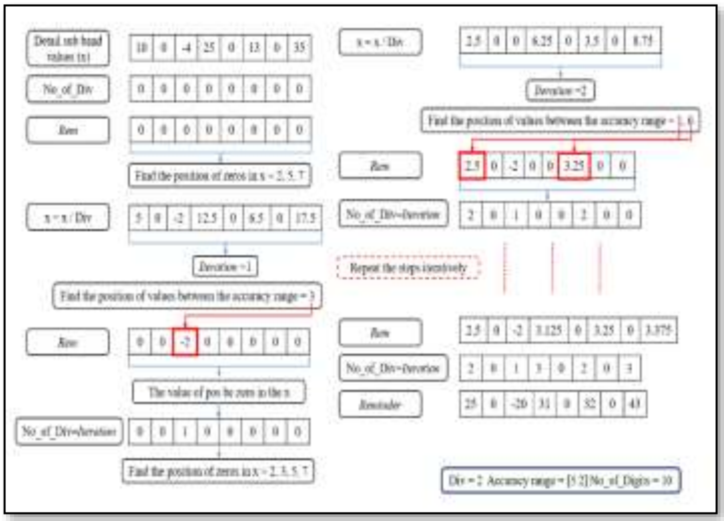

Figure 1. Example of iterative scalar uniform quantized process for details sub band of MSV.

v. Use the quantization matrix that illustrated in Fig. 3 to quantize the resulted transform *DCT* values [29].

$$\hat{C}(u,v) = Round\left(\frac{T(u,v)}{Q(u,v)}\right) \quad (7)$$

Where $\hat{C}(u,v)$ represents the quantized *DCT* coefficients, $T(u,v)$ represents a *DCT* coefficients, $Q(u,v)$ is a quantization matrix.

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Figure 2. Quantization matrix of JPEG base [9].

vi. The zigzag process is a significant step to order the quantized AC coefficients from low-frequency and high-frequency, with burden of insignificant values see Fig. 4 [9, 30].

vii. Create a multi row matrix: the resultant from zigzag

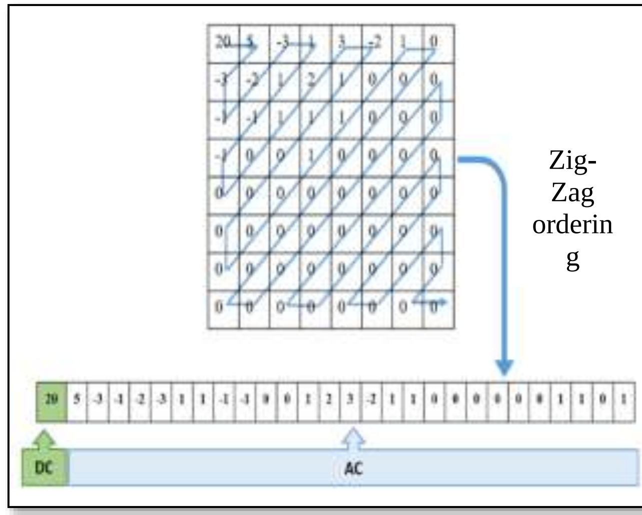

Figure 4. Zigzag scan process [30].

above is resized into a matrix of multi row, which aims to decrease the number of high frequency coefficients by eliminating uncorrelated values according to *NZ* part control parameters. The complementary step vii. involves isolating the DC, AC that are illustrated in the following two sub-steps:

a) DC coefficients correspond to the first element of multi row matrix, which are highly correlated embedded and generally coded using the differential base *DPCM* techniques see Eq. (9).

$$DC(i) = DC(i) - DC(i+1) \quad (8)$$

Where i =1, 2, 3… n^2-1, n^2 is the size of DC.

b) AC coefficients utilized *MMSA* encoding of a two key generation scheme of integer base see Eq. (9-12), also illustrated in algorithm (1)

$$Key_1 = Start\ value \quad (9)$$

$$MxVal = Round(Max(AC\_arr) + Max(AC_{arr})/0.5) \quad (10)$$

$$Key_2 = (Key_1 + MxVal) + \ Factor \quad (11)$$

$$MM_{AC}(i) = \sum_{t=m}^{Ms} Key_1 \times AC_{arr(t)} + Key_2 \times AC\_arr(t+1) \quad (12)$$

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Where Start value is a selected integer number for key1, MxVal is the maximum value of input AC coefficients, AC_arr correspond to AC coefficients of multi row base and Factor is the value added to the key generation, Ms corresponding to size of AC coefficients of multi row base, m=0, 2, 4, 6…is compressed two values of MMSA, increased by two and MMAC is the compressed minimized matrix of non-zero values of AC coefficients of two base.

Input: AC_arr which corresponding to array of non-zero values in AC coefficients
Output: KEY_1, KEY_2
Begin **Step 1:** Input initial value Start value = 1, Factor = 2 **Step 2:** Find maximum value of non-zero values in AC coefficients MxVal = Round (Max(AC_arr) +(Max(AC_arr) / 0.5)) **Step 3:** Compute Keys KEY_1 = Startvalue KEY_2 = (Startvalue + MaxVal) + Factor **End**

Algorithm -1 Key generator of 2 digits base [28].

viii. Finally, the entropy coding of arithmetic techniques is adopted on the compressed information to represent them with a smaller number of bits.

Step 5: Performing the following steps explains the **decoding process** by applying the inverse for the steps above to produce the reconstructed of $I_{Sr\text{ details MSV}}$ of detail sub bands of the three levels according to the Eq. (13-15), Also, Fig. 5 shows the proposed decompression system.

$$Reminer_{details} = \frac{Reminer}{No\_of\_Digits} \quad (13)$$

$$Values = 2^{Iteration} \quad (14)$$

$$\hat{I} = round(Values \times Reminer_{details}) \quad (15)$$

Step 6: Reshaped the decoded *MSV* of detail sub bands into *2-D* base.

Step 7: Apply the inverse of *DWT* of hierarchal scheme of each band to reconstruct the decoded source band image.

Step 8: Dequantized the inverse of *DWT* of hierarchal scheme of each band uniformity to reconstruct the decoded source band image.

Step 9: The decompression process (as shown in Fig. 4) is the inverse of the compression process, which means doing all of the above steps in the reverse order direction. The first step of the decompression process is arithmetic decoding, Then the decoding *MMSA* for non-zero values of AC coefficients to reconstructed the non-zero values of AC coefficients and apply the inverse *DPCM* on DC coefficients to reconstruct DC's values, followed by inverse multi row/zigzag matrices, and after that, applying de-quantization, *IDCT* and inverse normalization to reconstruct the decoded non-source bands image.

Step 10: Combination the bands to reconstruct approximated color image then converted back to RGB base $\hat{I}$.

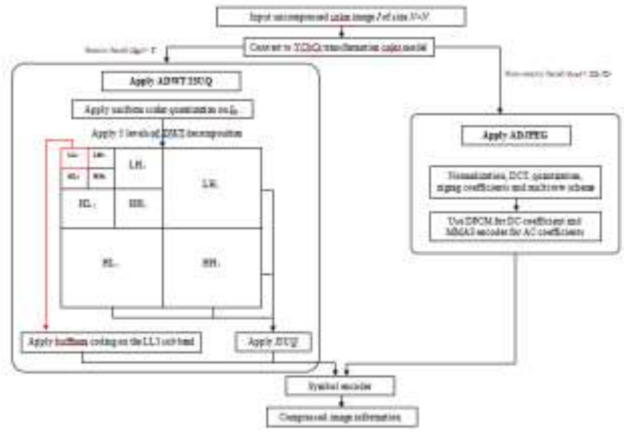

Figure 1. Structure encoding of the proposed system.

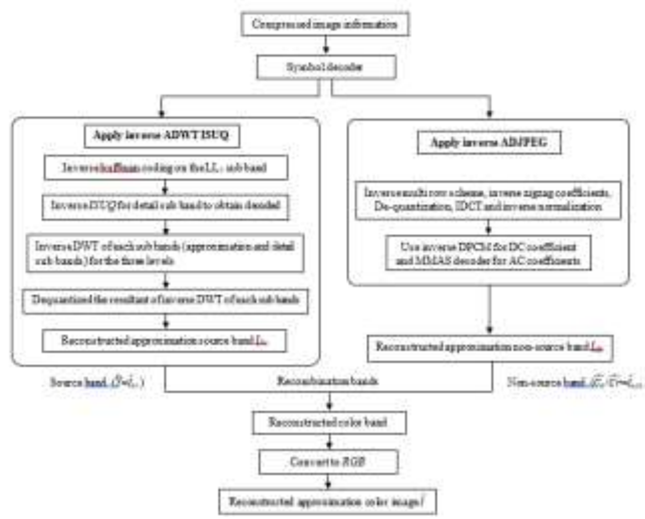

Figure 5. Structure decoding of the proposed system.

IV. RESULTS AND DISCUSSION

For testing the suggested compression system performance; three standard color square images of size 256×256 pixels adopted from (Miscellaneous) standard dataset, as shown in Fig. 6.

Two performances measures adopted, one for compression performance, namely the compression ratio measure, which is the ratio of the original image size in bytes to the compressed size of image information in bytes, the second one for quality performance of objective fidelity measure, namely the Peak -Signal-to Noise- Ratio (PSNR) between the original image I and the decoded image Î.

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$$PSNR(I,\hat{I}) = 10log_{10}\left(\frac{(\max imumgray\ scale\ of\ image)^2}{MSE}\right) \quad (16)$$

$$MSE(I,\hat{I}) = \frac{1}{n\times n}\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}[\hat{I}(i,j) - I(i,j)]^2 \quad (17)$$

a b c

Figure 6- The adopted images (a) Lena image, (b) Jelly image and, (c) Home image, all images of size 256×256 images.

Table 1 shows the considered dominant parameters, whose values have been tested in detail. The results are shown in Tables (2-3), which summarizes the compression ratio and *PSNR* used for the three tested images of source/non sources bands.

It is clear that the quantization techniques for the three levels of *DWT* along with *ADJPEG* of two lossless values base *MMSA* affected the performance of the proposed technique in terms of compression ratio and *PSNR*, where small values mean a small compression ratio and a high *PSNR*, and vice versa. For the source band (I_{Sr}) which is quantized uniformity and the three levels of *DWT* applied on the quantized I_{Sr}, where the approximation sub band of the third level encode using huffman coding method and details sub bands are quantized using *ISUQ* and the non-source bands using the *ADJPEG* of *MMSA* base.

Table 2 shows the *ISUQ* of *MSV* for the source band using a limited case of accuracy ([5 2], [2 1]) with two selected values of digits (*No_of_Digits*) (10), with size in bytes computed as below that implies the size of the $I_{Sr\ details\ MSV}$ along the overhead information (1 for number of division (*Div*), 1 for number of digits and 2 for accuracy range) with *CR* and *PSNR*.

$$Total\ Sizebyte\ details = Sizebyte\ for\ I_{Sr\ details} + Size\ of\ Overhead \quad (18)$$

Clearly, the system performance affected by the number of digits; increasing the number of digits led to increases in *CR* and decreases in size in bytes of details while maintaining the image quality.

Table 1 The selected values of the control parameters

Proposed compression system		Proposed compression system	
Parameter value	**Range value**	**Parameter value**	**Range value**
Div	2	Block size	8×8
Number of digits	10	NZ	16, 32
Accuracy Range	[5 2], [2 1]		

Table 2A The tested results of the source band of the proposed technique

Tested Image	Accuracy Range = [5 2]			
	No. of Digits	Total Size in bytes of MSV	CR	PSNR
Lena	10	2426	25.6601	35.6346
Jelly	10	1712	35.6174	38.6460
Home	10	1802	33.9565	37.5356

Table 2B The tested results of the source band of the proposed technique

Tested Image	Accuracy Range = [2 1]			
	No. of Digits	Total Size in bytes of MSV	CR	PSNR
Lena	10	3026	20.7787	39.1306
Jelly	10	1956	31.4472	40.5404
Home	10	2308	26.9031	40.0892

The non-source bands compressed using *ADJPEG* lossily, which implies the utilization of size 8×8, the number of non-zero part (*NZ*), which is equals either to 16 or 32, along two integer keys to preserve the image quality with achieve compression performance through the minimization of AC coefficients that illustrated in table (3).

$$Sizebyte\ I_{nSr} = Sizebyte\ for\ DC\ Sizebyte\ for\ MM_{AC} + Sizebyte\ for\ LD \quad (19)$$

Obviously, by increasing *NZ* value the measures of performances (size in bytes, *PSNR*) increasing; with reduction in key_2.

Table 3 The tested results of the non-source bands of the proposed technique

Tested Image	Non-source band1			Non-source band2	
	NZ	Size in bytes	PSNR	Size in bytes	PSNR
Lena	16	2038	41.2211	2287	40.4267
	32	2391	41.3834	2695	40.5959
Jelly	16	2318	45.1653	2344	44.9074
	32	2564	45.2348	2836	45.2099
Home	16	1926	43.1716	2212	42.6938
	32	2210	43.8516	2545	43.9517

Combining compressed color band information with complementary computation in terms of *CR* and *PSNR* using the following equations also Fig. 7:

$$CompAllBands = (Comp_{ISr} + Comp_{InSr1} + Comp_{InSr2}) \quad (20)$$

$$CRColor = (Original\ /\ CompAllBands) \quad (21)$$

$$PSNRavg = \left(\frac{PSNR_{ISr}+PSNR_{InSr1}+PSNR_{InSr2}}{3}\right) \quad (22)$$

Where CompAllBands size in bytes for all compressed bands, CompISr is compressed source band in bytes, CompInSr1, CompInSr2 are compressed non-source bands in bytes, CRColor compression ratio for all color band in image, PSNRavg average PSNR for all bands, PSNRISr source band PSNR, PSNRInSr1, PSNRInSr2 are PSNR for non-source bands. Table (4) compares the suggested compression system with JPEG, where the comparison entails the CR and PSNR

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measures with number of digits =10, accuracy range [5 2], NZ= 16, start value =1, factor =2. Comparing estimated compressed images of the suggested system base to JPEG, as shown in Fig. 8.

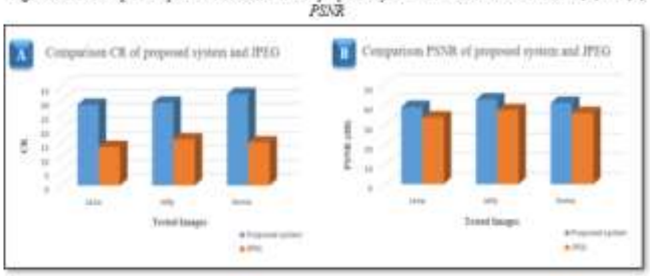
Table 4 The tested results of the non-source bands of the proposed technique

Tested Image	Proposed system			JPEG		
	$Comp_{Total}$	CR	$PSNR_{Avg}$	$Comp_{Total}$	CR	$PSNR_{Avg}$
Lena	6885	28.5560	39.0941	14438	13.6170	33.7775
Jelly	6708	29.3095	42.9063	12083.2	16.2711	37.4243
Home	6074	32.3688	41.1337	12902	15.2380	35.9990

Figure -7 The original and compressed images using the proposed system techniques
A. Original image **B.** Compressed image when No. of Digits = 10 and *NZ*=16 **C.** Compressed image when No. of Digits = 10 and *NZ*=32

Tested Image	A	B	C
Lena			
Peppers			
Home			

Figure -8 The comparison performance between the proposed system and standard *JPEG* in term (A) *CR* (B) *PSNR*



CONCLUSION

This paper investigates an effective lossy technique for compressing color natural images, where the main conclusions such as:

- The proposed system used uniform scalar quantization for I_{sr} color band along with DWT decompositions and iterative scalar uniform quantizer (*IUSQ*).
- The combination of quantization techniques efficiently improves results in terms of compression ratio and PSNR.
- The use of an iterative scalar uniform quantizer (*IUSQ*) with different number of digits improved compression performance.
- The utilization of *MMSA* for minimized AC coefficients of non-source bands overcome the *JPEG* inherited problems of large burden insignificant coefficients with attain high compression and preserving the image pleasantly.
- The mixing between source/non-source coding methods for suggested system better than utilizing the methods solely.

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