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The Use of Wavelet, DCT & Quadtree for Images Color Compression

Ali H. Ahmed*, Loay E. George
Department of Computer Science, College of Science, University of Baghdad, Baghdad, Iraq.

Abstract

The need for image compression is always renewed because of its importance in reducing the volume of data; which in turn will be stored in less space and transferred more quickly though the communication channels.

In this paper a low cost color image lossy color image compression is introduced. The RGB image data is transformed to YUV color space, then the chromatic bands U & V are down-sampled using dissemination step. The bi-orthogonal wavelet transform is used to decompose each color sub band, separately. Then, *the Discrete Cosine Transform* (DCT) is used to encode the Low-Low (LL) sub band. The other wavelet sub bands are coded using scalar Quantization. Also, the quad tree coding process was applied on the outcomes of DCT and quantization processes. Finally, the adaptive shift coding is applied as high order entropy encoder to remove the remaining statistical redundancy to achieve efficiency in the performance of the compression process.

The introduced system was applied on a set of standard color image; the attained compression results indicated good efficiency in reducing the size while keeping the fidelity level above the acceptable level, where it was obtained compression ratio which is around 1:40 for Color Lena, 1:30 for color Barbara.

Keywords: Lossy Image Compression, Wavelet Compression, DCT, Color Transforms, QuadTree Encoding.

استخدام التحويل المويجي وتحويل الجيب تمام وترميز الشجرة الرباعية لضغط الصور الملونة

علي حاتم احمد*، لؤي ادور جورج
قسم علوم الحاسبات ، كلية العلوم ، جامعة بغداد ، بغداد ، العراق.

الخلاصة

ان الحاجة لضغط الصور تحتاج دوماً الى التجديد، لما لها من أهمية في تقليل حجم البيانات؛ والتي بدورها سوف يتم تخزينها في مساحة أقل ونقلها بسرعة أكبر خلال قنوات الاتصال. في هذا البحث تم تقديم ضغط لصور ملونة بتكلفة محوسبة قليلة وبخسارة بسيطة للبيانات. يتم تحويل بيانات صورة RGB إلى لون الفضاء YUV، ثم يتم اعادة تعيين حزمتي اللونية U & V نحو مستوى اقل. بعد ذلك يستخدم التحويل المويجي الثنائي المتعامد لتحليل كل حزمة لونية على حدة. ثم يستخدم تحويل الجيب تمام المتقطع (DCT) لترميز الحزمة المنخفضة (التقريبية)) للتحويل المويجي. بعد ذلك يتم ترميز حزم المويجات الفرعية الأخرى (التفصيلية) باستخدام التكميم المتدرج الكمي. بعدها تم تطبيق عملية ترميز الشجرة الرباعية على نتائج عمليتي DCT والتكميم. وأخيرا، تم تطبيق التحول الترميز لإزالة التكرار الإحصائي المتبقيي في كل حزمة لتحقيق كفاءة عالية في عملية الضغط.

*Email: ali_ha_2012@yahoo.com

تم تطبيق النظام على مجموعة من الصور الملونة القياسية؛ وقدأشارت نتائج الضغط الى تحقيق كفاءة جيدة من حيث حجم البيانات المضغوطة مع الحفاظ على مستوى الدقة فوق المستوى المقبول، فقد تم الحصول على نسبة الضغط تبلغ حوالي 01:40 الى صورة لينا الملونة، 01:30 الى صورة باربرا.

Introduction

The need for data compression as a topic acquired its importance because it is a solution key for pypass the insufficient storage space and limited bandwidth of data transmission [1, 2]. The programs used to compress still images are, in fact, employ designed techniques that exploit unimportant sensory information and statistical redundancies. More images programmers rely on the use of two techniques (i.e., sub-band coding and transform coding). Sub-band coding decomposes signal into a number of sub-bands, using band-pass filter like wavelet transform [3]. Transform coding uses a mathematical transformation like DCT, and FFT.

An emergence interest was grown in the recent years about utilizing the benefits of wavelet coding to process both images and audio applications. The concept of wavelet coding, like other transform coding techniques, is based on the idea that the coefficients of transform decorrelates the samples values of the signal, such that they can be coded in more compressive way in comparison with the case of direct compression of the original samples values themselves [4].

The expected issues taken into consideration when developing the proposed system can be summarized as follows:

- Develop a system can get the benefits of existing spectral redundancy in the input image. The system should use the proper mapping equations to generate uncorrelated color image bands convey low data content.
- Decompose the image signal into sub bands each one conveys certain part of the signal that has specific spectral characteristic.
- Prune the existing local spatial correlation using transform coding.
- Developing a proper set of entropy encoders to efficiently prune the existing statistical redundancy may found in produced transformed data.
- The need for image compression algorithms that can operate concurrently to satisfy the conflicting demands by users; which are a high compression ratio and preserve the high accuracy in order to get a pure signal of the image. This matter has led researchers in the past two decades to establish several different coding methodologies.

Related Work

Gornale and et. al (2007) suggested a compression system based on the bi-orthogonal wavelet filters; because orthogonal filters have suitable property of energy preservation whereas biorthogonal filters lack of it. Since, Daubechies, Symlet and Coiflet filters have good property of energy conservation, more vanishing moments, regularity and asymmetry than other orthogonal filters; they were adopted in their suggested system. Also, they used bi-orthogonal wavelet filter out of Daubechies, Symlet and Coiflet for lossy fingerprint image compression. They have applied Daubechies, Symlet and Coiflet Wavelet Transforms (WT) through different orders at 1 to 5 decomposition levels on the fingerprint images [5].

Singh and et al. (2011) referred that the properties of wavelet transform greatly help in identification and selection of significant and non-significant coefficients amongst the wavelet coefficients, DWT represents image as a sum of wavelet function (wavelets) on different resolution levels. So, the basis of wavelet transform can be composed of functions satisfy the requirements of multi-resolution analysis. So, the choice of wavelet function for image compression depends on the image application and the content of image. They presented a review of the fundamentals of image compression based on wavelet. Also, they discussed important features of wavelet transform in compression of images. Finally, they evaluated and compared the compression performance of three different wavelet families (i.e., Daubechies, Coiflets, Biorthogonal) through measuring the image fidelity objectively (using peak signal-to-noise ratio) and subjectively (using visual image quality), beside to compression ratio [6].

Ruchika and et al. (2012) they proposed the use of DWT to compress wide variety of medical images. They indicated that the application of thresholds on DWT coefficients in addition to Huffman encoding leads to major reduction in image statistical redundancy [6]. The test results indicated that the system performance is promising when applied on medical images [7].

Shaymaa and et al. (2015) have proposed a lossy compression scheme uses different signal representation method. Firstly, they used cubic Bezier surface (CBI) representation to prune the image component that shows large scale variation. The produced cubic Bezier surface is subtracted from the image signal to get the residue component. Then, bi-orthogonal wavelet transform was applied to decompose the residue component. Finally they used some lossless coding method to boost the compression gain [8].

IMAGE COMPRESSION SYSTEM

Like any typical image compression schemes, the introduced system consists of two individual units: (i) image compressor used to compress real color still images with little rate of subjective distortion, and (ii) image decompressor (reconstructor) used to retrieve the raster image. In the following sections details for the implied stages of each unit are given.

The Proposed Lossy Image Compressor

As shown in Figure-1 this unit consists of the following stages:

A. Image Loading: Initially, the input image is loaded as bitmap (raster) formatted. Then, the loaded image data is analyzed the basic color components (RGB).

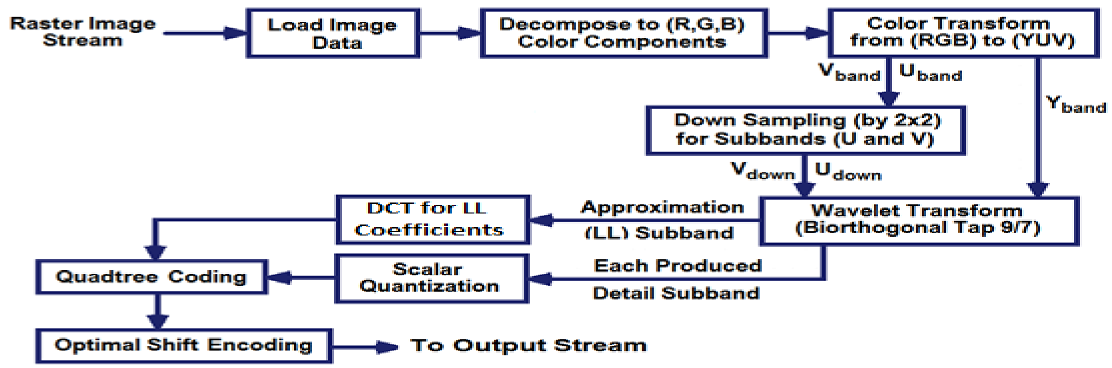

Figure 1- The layout of proposed lossy image compressor.

B. Color Transform: The advantage of dealing with the color representation YUV is to get proper image data representation that is closer to performance nature of human vision system (HVS); the intensity band (i.e., Y) is the most, subjectively, informative channel of the color image; while the bands U and V, normally, convey less subjective information.

C. Chromatic Bands Downsampling: Since the chrominance components (U and V) holds only 10% of the whole image information and HVS doesn't have high spatial resolution against these band; so these bands are down sampled by 2 to produce the down sampled components (i.e., U_{down} & V_{down}). This down sampling will cause insignificant subjective distortions in the color image.

D. Biorthogonal Wavelet Transform: In this paper, the bi-orthogonal wavelet transform (tap 9/7) is used as spatial signal decomposer for each subband, individually. Bi-orthogonal wavelet decomposition was chosen due its compressive efficiency, and modern wide use in standards lossless & lossy compression scheme (for example in ISO JPEG2000 standard). In wavelet transform coding the image is divided into four subbands each one can easily encoded separately.

The bio-orthogonal tap 9/7 wavelet filters are applied to the (Y, U_{down} and V_{down}) color bands separately. The transform will decompose the data of each colors band into four subbands (i.e., LL, LH, HL and HH). The following set of equations describes the four “lifting” steps and the two “scaling” steps applied to accomplish the bi-orthogonal (9/7) wavelet decomposition [8]:

$$Y_{2n+1} = X_{2n+1} + a\, X_{2n} + X_{2n+2} \quad , \qquad (1)$$

$$Y_{2n} = X_{2n} + b\, Y_{2n-1} + Y_{2n+1} \quad , \qquad (2)$$

$$Y_{2n+1} = Y_{2n+1} + c\, Y_{2n} + Y_{2n+2} \quad , \qquad (3)$$

$$Y_{2n} = Y_{2n+1} + d\, Y_{2n-1} + Y_{2n+1} \quad , \qquad (4)$$

$$Y_{2n+1} = -K\, Y_{2n+1} \quad , \qquad (5)$$

$$Y_{2n} = (1/K)\, Y_{2n} \quad , \tag{6}$$

Where, X() is the input array & Y() is the wavelet transform outcome array (i.e., the approximation & detail coefficients). The values of the (a, b, c, d, K) parameters are:
a=-1.58613434, b=-0.0529801185, c=-0.8829110762
d=-0.4435068522, K=1.149604398

E. DCT: The approximation subband (LL) is passed through the DCT transform coding, The mathematical representation for Two-dimensional DCT is [9]:

1. The forward 2D DCT equation is:

$$G_{ij} = \sqrt{\frac{4}{nm}}\, C_i C_j \sum_{i=0}^{n-1}\sum_{j=0}^{m-1} p_{xy} \cos\left[\frac{(2y+1)j\pi}{2m}\right] \cos\left[\frac{(2x+1)i\pi}{2n}\right] , \tag{7}$$

For $0 \le i \le n-1$ and $0 \le j \le m-1$ and for Ci and Cj

2. The inverse 2D DCT equation is [9]:

$$p_{xy} = \sqrt{\frac{4}{nm}}\, C_i C_j \sum_{i=0}^{n-1}\sum_{j=0}^{m-1} C_i C_j G_{ij} \cos\left[\frac{(2x+1)i\pi}{2n}\right] \cos\left[\frac{(2y+1)j\pi}{2m}\right] , \tag{8}$$

For $0 \le x \le n-1$ and $0 \le y \le m-1$
Where,

$$C_f = \begin{cases} \frac{1}{\sqrt{2}}, & f = 0 \\ 1, & f > 0 \end{cases}$$

The process of Passing the $LL_{Subband}$ throw the DCT is illustrated in Figure-2 shown below.

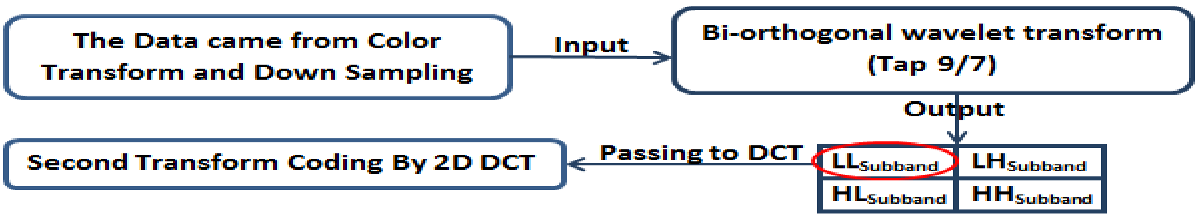

Figure 2 - The process of passing the $LL_{Subband}$ values

F. Quantization: Quantization is simply the process of reducing the number of bits that are needed to store the values of coefficients by reducing their accuracy, the main objective of quantization is to reduce the high-frequency coefficients least importance to zero. In the proposed system, the uniform scalar quantization operation was adopted to quantize the coefficients of each sub band individually; this step will reduce the number of bits needed to represent the coefficients approximately, and preparing it to the shift coding step. The coefficients of each subband are quantized with an appropriate quantization step value (Qstp). The transform coefficients are categorized according to its subband membership to (L_n, H_n… H_2, H_1). The rounded subband (L_n) coefficients are quantized using low quantization step, which is always smaller than the quantization step used to quantize the detail subbands' coefficients. Also, the quantization step of the high level detail subband coefficients is smaller than that for low level subband.

In the proposed system, a hierarchal relationship was adopted to determine the value of scalar quantization step that used to quantize the wavelet (i.e., detail) coefficients belong to each subband, separately. The way of selecting the variation nature of quantization step across the subbands was based on the criteria "diminishing the range of wavelet coefficients values without making significant degradation in image quality". The adopted hierarchal scalar quantization step was governed by the following equations [8]:

$$Q_{step}(n) = \begin{cases} Q\alpha^{n-1} & for\ LH\ and\ HL\ subbands \\ Q\beta\alpha^{n-1} & for\ HH\ subbands \end{cases} \quad (9)$$

Where, $Q_{step}(n)$ is the quantization step of n^{th} subband; α is the rate of increase of quantization step its value should be less than 1; β is the additional ratio for quantization step for HH subband, its value is always (≥1).

G. Quadtree Coding: In this step, the process of quadtree coding is applied to encode the quantized detail bands (i.e., LH, HL & HH) subbands of (Y, U_{down}, and V_{down}). The quadtree method divides the subband into four equal sized square blocks. Then, each block is tested to check if it has at least non-zero coefficient value (i.e., not empty) or not (i.e., empty). In case the tested block is not empty it will be divided into four sub-blocks, and made the search process on the sub-blocks (4x4) is retested alone. This process begins with whole subband quantized coefficients and stops when reaching to the smallest sub-blocks have size (2x2); if that block is not empty then its 4 coefficients values are stored in a temporary buffer, Buf(), along with the quadtree partitioning binary code.

H. Entropy Encoding Using Shift Coding: The last step of the proposed image compressor unit is applying lossless compression of the non-empty blocks coefficients which are already registered in temporary buffer Buf(). Figure-3 illustrates the layout of the developed entropy coder; which is designed to remove the statistical redundancy efficiently.

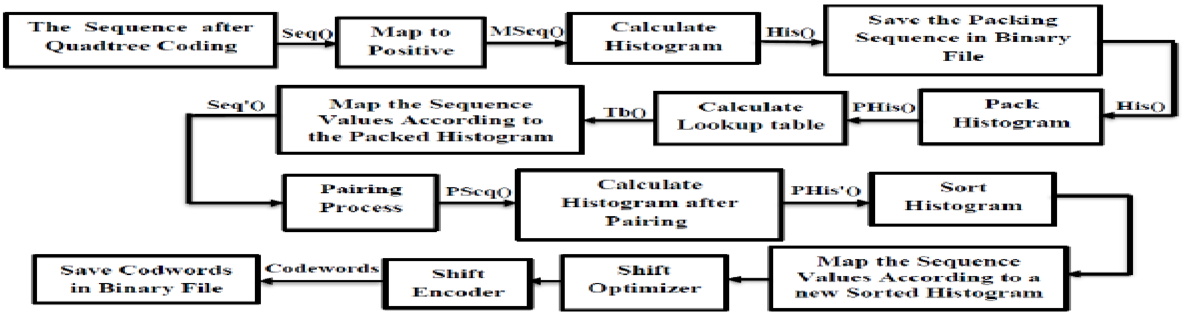

Figure 3- The Layout of the Enhanced Shift-key Encoder

The histogram of sequence of data registered in Buf() is concentrated around the high peak located at the value (0). Therefore, the use of shift coding will be appropriate for the entropy encoding the data to attain high compression gain. The implanted enhanced shift coder implies the following steps:

i. **Mapping to Positive:** This step maps the sequence elements values to be positive numbers. This step makes the coding process of the next step easier. This mapping step is done be representing each negative element value as positive odd number, and each positive value is represented as even number. This conversion can be applied using the following simple mapping equation [8, 9]:

$$m_{out}(i) = \begin{cases} 2m_{in}(i) & if\ m_{in}(i) \geq 0 \\ -2m_{in}(i) + 1 & if\ m_{in}(i) < 0 \end{cases} \quad (10)$$

Where, $m_{in}(i)$ is the mapped i^{th} sequence element; $m_{out}(i)$ is the corresponding mapped value.

ii. **Histogram Packing:** The histogram of the positive sequence elements will show long tail with long many gaps places (i.e., many values doesn't occur in the sequence); this leads to significant reduction of the compression gain when using shift encoder. So, it is proper to make a compaction in the histogram values. Then, the positive buffer's elements values are remapped according to the packed histogram elements.

iii. **Elements Pairing Stage:** This step is applied to detect the most redundant pair of subsequent elements, and replace the pair by single value (i.e., Max+1), where Max is highest registered value of all elements. After each pairing step increment Max value by 1. The pairing operation can be repeated for a number of times (M); where M is a predefined parameter value.
After the Pairing step, the new histogram of the produced sequence is calculated and stored as overhead information is compression stream, because it is necessary to do the decoding operation. Then, it is sorted in descending order and re-maps the elements values according to the indexes of their values in the histogram.

iv. **Determination of Optimal Shift Key Value:** According to shift key encoding mechanism, the small valued symbols which have high occurrence probabilities are assigned short codewords, while the large values symbols are assigned long codewords. So, for determining the optimal key value that separating the short codewords from the long ones, an optimizer algorithm was introduced. This optimizer search for the best short codeword length (n_S) and the corresponding long codeword (n_L) lead to lowest value of total bits (T_{Bits}) required to encode the whole input symbols; that is [8, 9]:

$$T_{bits} = n_S \sum_{i=0}^{2^S-1} His(i) + n_L \sum_{i=2^S-1}^{M} His(i) \quad (11)$$

Where, His(i) is the i[th] histogram value; M is the highest value of the input elements to the shift encoder.

v. **Shift Encoding:** As last step, the traditional shift encoding step is applied such that the small coded element is coded using the leading bit value "0" concatenated with n_S bits used to represent the element value; while the large valued element is coded using the leading bit value "1" concatenated with n_L bits used to represent the element value.

Image Decompressor Unit

Figure -4 presents the layout of the Proposed Image Decompressor. The order of the corresponding inverse operations (to those used in image compressor) is arranged in reverse order.

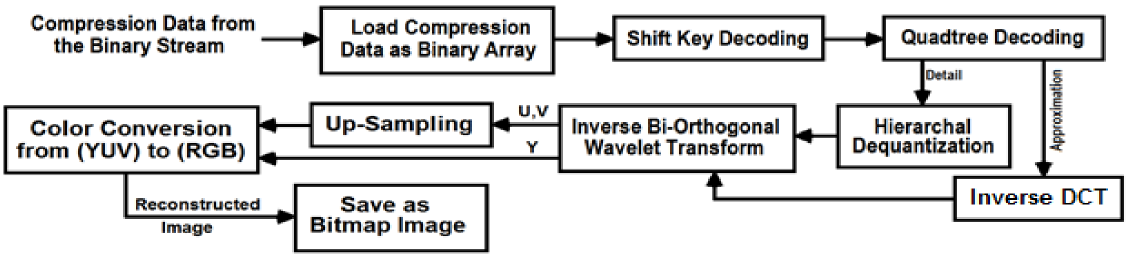

Figure 4- Decoding Process

Also, Figure -5 presents the layout of the corresponding shift key decoder.

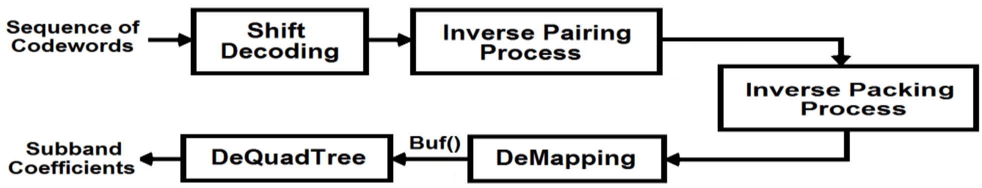

Figure 5- Entropy Decoder

Results and Discussion

Different sets of tests been performed to evaluate the performance of the proposed color image compression system in terms of Compression ratio (CR), Peak Signal to Noise ratio (PSNR). The effectiveness of the following system parameters was investigated:

(1) The number of wavelet passes (Npass)
(2) Initial quantization step (Q) for the detail subbands coefficient (LH, HL, and HH)
(3) The descending rate parameter (α)
(4) Beta increment ratio (β).

Table-1 lists the specifications of the standard images used as test material in this paper work. Table-2 presents the default values for the investigated parameters.

Table 1- the Characteristics of the Tested Standard Images.

Characteristic	Color Lena	Color Barbara	Gray Barbara
Bit depth (bit)	24	24	8
Dimension	256x256	256x256	256x256
Size (KB)	192	192	192

Table 2- the Default Values of the Control Parameters for all images.

Parameter	Default Value		Range
	Color Lena, Barbara	Gray Barbara	
QS_Y	35	35	[10,50]
$QS_{UD,VD}$	35	35	
α_y	0.5	0.5	[0.1,0.9]
$\alpha_{UD,VD}$	0.5	0.5	
β_y	1.6	1.6	[1.1,1.9]
$\beta_{UD,VD}$	1.6	1.6	
N_{pass}	3	3	[1,4]
BS_{Size}	16	16	[2,32]

Tables –3 , 4 and 5 lists the attained performance parameters of the proposed system when applied on color Lena, Barbara and gray Barbara, respectively using different number of passes; the listed results indicate acceptable compression results in terms of (CR), fidelity measures (PSNR) can be reached. So that in each test group in tables.

Table 3-Test Results for Color Lena image.

NoPass	BS	Alpha	beta	Qstep	CR	PSNR	MSE	Time (in seconds)	
								Encode	Decode
1	16	0.5	1.6	35	9.80	31.05	51.01	0.57	0.58
2	16	0.5	1.6	35	18.23	28.82	85.15	0.29	0.17
3	16	0.5	1.6	35	24.24	27.72	109.79	0.25	0.08
4	16	0.5	1.6	35	23.75	27.26	122.19	0.27	0.06
3	**2**	0.5	1.6	35	26.36	27.74	109.22	0.24	0.05
3	**4**	0.5	1.6	35	24.94	27.74	109.22	0.24	0.05
3	**8**	0.5	1.6	35	25.08	27.74	109.39	0.28	0.05
3	**16**	0.5	1.6	35	25.40	27.72	109.79	0.25	0.10
3	**32**	0.5	1.6	35	25.50	27.68	110.86	0.34	0.17
3	16	**0.5**	1.6	35	29.08	27.72	109.79	0.24	0.08
3	16	**0.6**	1.6	35	31.37	26.84	134.59	0.25	0.07
3	16	**0.7**	1.6	35	36.38	26.20	155.86	0.24	0.07
3	16	**0.8**	1.6	35	42.61	25.60	179.06	0.25	0.08
3	16	**0.9**	1.6	35	48.59	25.08	201.64	0.22	0.08
3	16	0.5	**1.5**	35	28.46	27.75	109.11	0.24	0.09
3	16	0.5	**1.6**	35	25.78	27.72	109.79	0.25	0.07
3	16	0.5	**1.7**	35	25.93	27.67	110.94	0.36	0.07
3	16	0.5	**1.8**	35	26.07	27.64	111.87	0.28	0.07
3	16	0.5	**1.9**	35	26.40	27.61	112.58	0.28	0.08
3	16	0.5	1.6	**30**	21.07	28.23	97.71	0.30	0.07
3	16	0.5	1.6	**35**	24.80	27.72	109.79	0.33	0.07
3	16	0.5	1.6	**40**	29.00	27.20	123.87	0.25	0.07
3	16	0.5	1.6	**45**	33.23	26.74	137.52	0.24	0.07
3	16	0.5	1.6	**50**	36.93	26.44	147.44	0.24	0.08

Table 4- Test Results for Color Barbara Image.

NoPass	BS	Alpha	beta	Qstep	CR	PSNR	MSE	Time (in seconds)	
								Encode	Decode
1	16	0.5	1.6	35	8.78	28.43	93.26	0.56	0.61
2	16	0.5	1.6	35	14.67	26.79	136.07	0.40	0.19
3	16	0.5	1.6	35	18.44	25.88	167.79	0.32	0.07
4	16	0.5	1.6	35	18.11	25.53	181.88	0.32	0.05
3	2	0.5	1.6	35	19.95	25.89	167.42	0.28	0.05
3	4	0.5	1.6	35	18.85	25.89	167.42	0.28	0.05
3	8	0.5	1.6	35	19.00	25.88	167.58	0.37	0.07
3	16	0.5	1.6	35	19.12	25.88	167.79	0.32	0.07
3	32	0.5	1.6	35	19.15	25.87	168.12	0.38	0.18
3	16	**0.5**	1.6	35	21.88	25.88	167.79	0.27	0.08
3	16	**0.6**	1.6	35	22.24	25.28	192.48	0.28	0.07
3	16	**0.7**	1.6	35	24.90	24.67	221.35	0.37	0.08
3	16	**0.8**	1.6	35	27.58	24.12	251.67	0.32	0.07
3	16	**0.9**	1.6	35	29.76	23.68	278.33	0.24	0.08
3	16	0.5	**1.5**	35	21.39	25.92	166.22	0.30	0.08
3	16	0.5	**1.6**	35	19.40	25.88	167.79	0.30	0.08
3	16	0.5	**1.7**	35	19.61	25.83	169.74	0.33	0.08
3	16	0.5	**1.8**	35	20.06	25.77	171.84	0.28	0.07
3	16	0.5	**1.9**	35	20.51	25.73	173.49	0.32	0.08
3	16	0.5	1.6	**30**	15.05	26.47	146.41	0.33	0.07
3	16	0.5	1.6	**35**	18.51	25.88	167.79	0.29	0.07
3	16	0.5	1.6	**40**	22.16	25.38	188.03	0.26	0.07
3	16	0.5	1.6	**45**	26.12	24.99	206.04	0.25	0.07
3	16	0.5	1.6	**50**	30.33	24.63	223.89	0.23	0.07

Table 5- Test Results for gray Barbara Image.

NoPass	BS	Alpha	beta	Qstep	CR	PSNR	MSE	Time (in seconds)	
								Encode	Decode
1	2	0.5	1.6	35	40.81	37.92	10.48	0.40	0.25
2	2	0.5	1.6	35	22.62	36.47	14.65	0.41	0.06
3	2	0.5	1.6	35	15.92	36.08	16.02	0.37	0.04
4	2	0.5	1.6	35	13.02	35.99	16.33	0.36	0.03
1	**2**	0.5	1.6	35	16.33	36.09	15.96	0.30	0.03
1	**4**	0.5	1.6	35	15.05	36.09	15.98	0.30	0.03
1	**8**	0.5	1.6	35	15.25	36.08	16.02	0.42	0.03
1	**16**	0.5	1.6	35	15.35	36.04	16.14	0.37	0.08
1	**32**	0.5	1.6	35	15.38	35.97	16.44	0.38	0.26
1	2	**0.5**	1.6	35	18.06	35.30	19.17	0.36	0.03
1	2	**0.6**	1.6	35	21.27	34.47	23.18	0.31	0.03
1	2	**0.7**	1.6	35	24.37	33.72	27.57	0.322	0.03
1	2	**0.8**	1.6	35	27.43	32.88	33.49	0.30	0.03
1	2	**0.9**	1.6	35	30.39	32.06	40.44	0.30	0.03
1	2	0.5	**1.5**	35	15.587	36.015	16.276	0.34	0.035
1	2	0.5	**1.6**	35	15.937	35.931	16.592	0.32	0.038
1	2	0.5	**1.7**	35	16.291	35.878	16.795	0.33	0.033
1	2	0.5	**1.8**	35	16.668	35.801	17.097	0.36	0.039
1	2	0.5	**1.9**	35	17.036	35.747	17.313	0.32	0.034
1	2	0.5	1.6	**10**	6.43	40.75	5.46	0.67567	0.04
1	2	0.5	1.6	**20**	10.62	37.12	12.593	0.46	0.03
1	2	0.5	1.6	**30**	17.43	35.13	19.94	0.29	0.03
1	2	0.5	1.6	**40**	26.25	33.73	27.50	0.26	0.03
1	2	0.5	1.6	**50**	36.09	32.80	34.12	0.22	0.03

In all conducted tests, the values of three parameters were fixed and the value of the fourth parameter was changed to define its effectiveness on the compression system performance. The results listed in above tables indicate the following remarks:

1. In general, an increase in CR is occurred when values of the parameters (number of Passes**,** $\mathbf{Q_{step}}$**,** **α, β**) are increased, all an associated decrease occurred in PSNR and an increase in MSE, Except grayscale images because it is composed of single band Therefore, we find a small differences in its results
2. The parameter Q_{step} is the most effective parameter on the compression performance; its increase causes significant increase on CR and decease in PSNR**.**
3. The parameter No. of Passes has significant impact compression performance; its increase shows an increase in CR and decrease in PSNR. But in general it is less effective in comparison with $\mathbf{Q_{step}}$.
4. The parameter **β** is less effective on CR, PSNR and MSE.
5. Generally, the value of MSE is increased when increasing the value of any one of the four parameters. But, this increase varies according to the parameter type; the largest dependency is **α** and the least dependency is with **β**.

Table-5 lists the compression results when the method is applied on Lena image; we can notice the effectiveness of applying DCT on the proposed system which get high CR and better quality (PSNR).

Table 6-Test Results for Color Lena image with and without implementation DCT.

No.Pass	CR	PSNR	MSE	Time (in seconds)	
				Encode	Encode
Without implementation DCT					
1	8.11	29.78	68.28	0.47	0.04
2	15.41	28.35	94.92	0.25	0.03
3	25.77	27.38	118.62	0.31	0.04
4	33.40	26.86	133.86	0.24	0.04
With implementation DCT					
1	26.53	29.92	66.20	0.55	0.58
2	41.11	28.45	92.81	0.32	0.17
3	45.77	27.46	116.53	0.25	0.08
4	50.06	19.97	653.63	0.23	0.05

The results show clearly an increase in CR is occurred when DCT is applied; also insignificant change in PSNR and MSE is occurred. Figure-6 shows samples of reconstructed image produced by the proposed method with the original image.

Figure 6- Samples of Compression Results

Table 7-The best compression results when DCT was applied.

Image	Qs	α	β	BS_{SIZ}	N_{Pass}		PSNR
Color Lena	35	0.2	1.9	16	2	41.25	30.08
	35	0.4	1.9	16	3	58.75	28.39
Color Barbara	25	0.4	1.9	16	2	34.13	28.15
	35	0.3	1.9	16	3	37.17	27.01
Gray Barbara	35	0.9	1.9	16	3	105.85	30.25

Comparisons with Previous Studies

Many methods for image compression have been developed in the past few years. In this section the results of our proposed schemes have been compared with some previously published methods. Table-8 lists the CR and PSNR attained by our proposed schemes with those given in previous studies, taking into consideration that in these studies same images have been used. The listed results demonstrate that our proposed scheme outperforms other methods.

Table 8- Comparison between the performance results of several image compression methods, (Not Mentioned (NM)).

Author	Method	Image	CR	PSNR (in	Details	
					Bit	Size
[Har08]	Quadtree to compress gray images	Lena	4.72	NM	8	64
		Barbara	3.7	NM	8	64
[Sid09]	Discrete Wavelet Transform (DWT), RLE, Arithmetic coding, and Shift Number Coding (SNC) have been used to compress gray images.	Lena	5.76	31.5	8	64
[Kri11]	The Bio-orthogonal Tap 9/7 Wavelet filters applied on photographic images (monochrome and color).	Lena	12.05	26.89	24	64
[Geo11]	Biorthogonal wavelet transform (Tap 9/7), 2D polynomial representation, quantization, quadtree coding, and shift encoder have been applied to compress color images.	Lena	13.6	30.12	24	192
[Gup13]	The combinations of Integer Wavelet Transforms (IWT) and Predictive	Lena	8.0	NM.	8	64
		Barbara	7.0	NM.	8	64
[Kha13]	Quadtree, polynomial, uniform scalar quantization, and Huffman coding have been used to compress gray images.	Lena	5.412	NM.	8	64
[Shay16] (only CBI)	Cubic Bezier Interpolation, Tap 9/7 Wavelet, Quadtree and High Order Shift Coding have been applied to compress monochrome and color	Lena	19.0	30.04	24	192
		Lena	6.09	31.35	8	64
		Barbara	11.8	30.07	24	192
		Barbara	5.06	30.18	8	64
[Shay16] (BP)	Cubic Bezier Interpolation, Tap 9/7 Wavelet, Polynomial Approximation, Quadtree and High Order Shift Coding have been applied to	Lena	16.1	30.12	24	192
		Lena	6.02	32.15	8	64
		Barbara	10.7	30.01	24	192
		Barbara	5.01	31.49	8	64
Proposed scheme DCT	Tap 9/7 Wavelet, DCT, Quadtree and High Order Shift Coding have been applied to compress monochrome and color images	Lena	19.1	34.84	24	192
		Barbara	11.7	33.92	24	192
		Lena	6.10	42.77	8	64
		Barbara	5.04	41.84	8	64

Looking at the results that have been obtained and compared with the results obtained by Shaymaa and et. al (2015) for images Lena and Barbara; will see that we were able to get good compression ratio and higher image quality and a relatively short time,(in all cases the range of encoding ,decoding time was in(0.3 to 0.7 second). And this is a good.

The results show that the proposed system was able to competition the previous studies strongly, so that when we use the same compression ratio (CR), we could get an image quality (PSNR) higher than obtained in the previous studies.

CONCLUSIONS

In this paper, an image compression scheme based on using DCT, wavelet, Quadtree and high order shift coding had been introduced. The following remarks are stimulated:

a. The use of DCT had improved the compression performance (i.e., increase the CR while preserving the image quality).
b. The increase in quantization step causes an increase in compression ratio and a decrease in PSNR value.

c. Q_{step} is the most effective parameter on compression performance; while the parameter β is the less effective one.
d. As a future work using image fractal coding as compression tool (instead of DCT and/or Wavelet transform coding) in the compressive image.

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