British Journal of Applied Science & Technology
11(4): 1-11, 2015, Article no.BJAST.20480
ISSN: 2231-0843

SCIENCEDOMAIN *international*
www.sciencedomain.org

The Use of Cubic Bezier Interpolation, Biorthogonal Wavelet and Quadtree Coding to Compress Color Images

Shaymaa D. Ahmed[1*], Loay E. George[1] and Ban N. Dhannoon[2]

[1]Department of Computer Science, College of Science, Baghdad University, Baghdad, Iraq.
[2]Department of Computer Science, College of Science, Al-Nahrain University, Baghdad, Iraq.

Authors' contributions

This work was carried out in collaboration between all authors. All authors participated in designing, software developments, testing and evaluation of proposed system, and confirmed the attained performance results. Authors SDA, LEG and BND approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/20480
Editor(s):
(1) Samir Kumar Bandyopadhyay, Department of Computer Science and Engineering, University of Calcutta, India.
Reviewers:
(1) Anonymous, University of Mining and Technology, China.
(2) M. A. Rizvi, National Institute of Technical Teachers' Training and Research, Bhopal, India.
Complete Peer review History: http://sciencedomain.org/review-history/11224

Original Research Article

Received 29th July 2015
Accepted 14th August 2015
Published 1st September 2015

ABSTRACT

In this paper, an efficient method for compressing color image is presented. It allows progressive transmission and zooming of the image without need to extra storage. The proposed method is going to be accomplished using cubic Bezier surface (CBI) representation on wide area of images in order to prune the image component that shows large scale variation. Then, the produced cubic Bezier surface is subtracted from the image signal to get the residue component. Then, bi-orthogonal wavelet transform is applied to decompose the residue component. Both scalar quantization and quad tree coding steps are applied on the produced wavelet sub bands. Finally, adaptive shift coding is applied to handle the remaining statistical redundancy and attain efficient compression performance.

The results of conducted tests indicated the developed compression system shows outstanding compression performance. The compression ratio is increased with the increase of wavelet's passes and with decrease of block size.

**Corresponding author: E-mail: shaymaadhyaa@yahoo.com;*

Keywords: Lossless image compression; transform coding; wavelet compression; shift coding.

1. INTRODUCTION

With the coming of internet, huge number of images is transmitted [1]. Uncompressed images can take a lot of memory in RAM and in storage media, and they can take more time to transfer from one device to another [2]. Thus Memory space and bandwidth limit are the real difficulties during image transmission [1]. Hence the fundamental aim of image compression is to decrease the storage space needed to store an image and to decrease the required time to transfer the image. Reduction in the size of image permits to proficiently use the memory or disk space [3].

During the last several years, wavelet transformations have achieved widespread acceptance, particularly within image compression research. Wavelets are also chosen as basic functions in JPEG 2000 [4], and one of the most imperative processing components of image compression is wavelet transform [5].

In this paper, CBI is applied on image to prune the large scale components of (Y,U,V) bands of image, then Biorthogonal Wavelet transform is applied on the residual component of Bezier image to transform the pixels in the uncompressed image into frequency domain coefficients (called transform coefficients). These coefficients have various desired properties. One is the energy compaction property that results in most of the energy of the uncompressed data being centered in only a little of the considerable transforms coefficients. This is the essential of achieving the compression [6].

In a wavelet compression system, the entire image is transformed and compressed as a single data object rather than block by block as in a DCT-based compression system. It allows uniform distribution of compression errors across the entire image [7], the resulting transform coefficients are quantized using uniform scalar quantization. Then, the quantized values are represented using quadtree encoding to prune the sparse blocks, followed by an improved shift coding algorithm.

2. PREVIOUS WORKS

1. Thanoon and George [8] have proposed a system utilizes 9/7 biorthogonal wavelet transforms, and then Discrete Cosine Transform (DCT) and quadtree coding are used to compress the approximate and detail subbands, respectively. A hierarchal quantization scheme was applied to reduce the number of bits required to encode the wavelet coefficients. Quadtree encoding was utilized as a further step to encode the quantized wavelet coefficients. The test results indicated that the proposed compression scheme shows good performance aspects.

2. Chen et al. [9] presented a near lossless medical image compression scheme based on combined JPEG-LS with cubic Spline interpolation (CSI). The CSI was developed to subsample image data with minimal distortion and to achieve image compression. The system led to high compression ratio and higher subjective quality when its results are compared with the outcomes of some standard transform-based codecs.

3. Muthaiah et al. [6] introduced a new dimension of image compression based on using random pixels of irregular sampling and image reconstruction that based on CSI techniques. The presented results showed the system can provide better efficiency both in pixel reconstruction and color reproduction.

4. George and Sultan [10] presented an image coding scheme based on wavelet transform, polynomial representation and quadtree coding. They proposed a scheme which uses the biorthogonal (tap 9/7) wavelet transform to decompose the image signal, and 2-D polynomial representation. Polynomials are utilized to prune the existing high scale variation of image signal. Also, they applied quantization with quadtree coding to compress the detail band and the residue part of approximation subband. Finally the results are further encoded using shift encoder as an efficient entropy encoder.

5. Sharmila and Kuppusamy [11] have proposed a combination of DCT, fractal with quadtree technique and Run Length Encoding to compress the image. The test results showed that the proposed scheme can compress the color image in better way, and the attained PSNR values

indicate that the proposed scheme reduces the noises in the decompressed image in better way.

3. THE PROPOSED METHODOLOGY

The proposed system consists of the first four preprocessing stages; Description of these stages is explained in the following subsections (as shown in Fig. 1).

3.1 Image Data Loading

In this stage, the data of image file is loaded and, the loaded data is separated into three arrays (R, G, B) each holds the data of certain color components.

3.2 Image Partitioning

Expanding vertically and horizontally the three arrays (R, G, B), if it is needed, according to a predefined block size, so that the width and height values of the expanded image will be multiples of block size value.

Image horizontal expansion is needed if the image width (W) is not multiple of block length (L_{Block}). Also, in case the image height (H) is not multiples of block length (L_{Block}) then vertical expansion is needed to expand [12].

Image expanding is done by adding a number of columns or rows according to the values of image width & height and to the predefined value of block size. Fig. (2) presents an illustrative example, when the size of image is taken 8x8 and the block size is 3.

The number of required added columns (n_{column}) or rows (n_{row}) can be determined according the following steps:

$$N_x = \left\lfloor \frac{W + L_{Block} - 1}{L_{Block}} \right\rfloor \quad (1)$$

$$W' = N_x \times L_{Block} \quad (2)$$

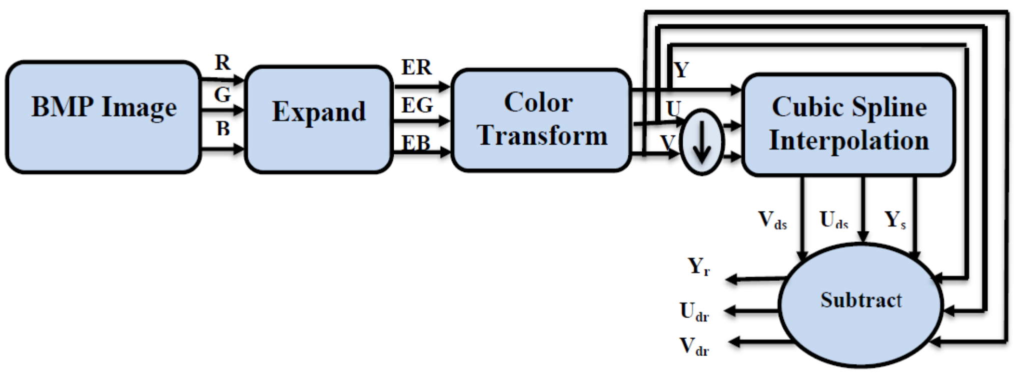

Fig. 1. The first four preprocessing stages of the proposed system

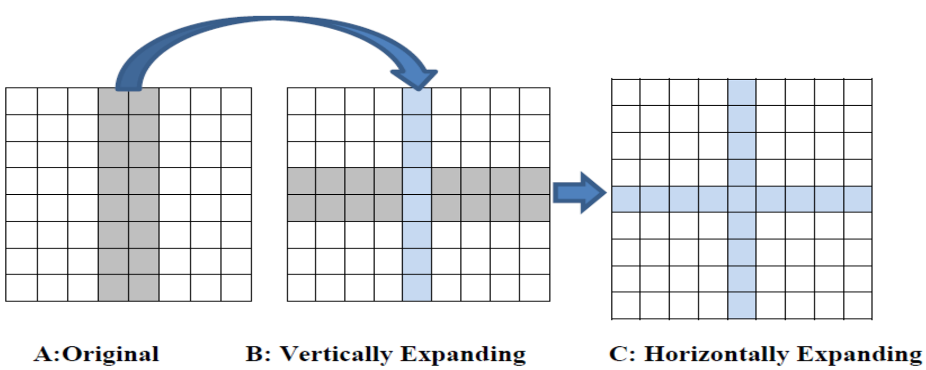

Fig. 2. Example of image expansion process

$$n_{column} = W' - W \tag{3}$$

$$N_y = \left\lfloor \frac{H + L_{Block} - 1}{L_{Block}} \right\rfloor \tag{4}$$

$$H' = N_y \times L_{Block} \tag{5}$$

$$n_{row} = H' - H \tag{6}$$

Where, N_x is number of blocks aligned horizontally; N_y is number of blocks aligned vertically; *W'* is the new width value; *W'* is the new width value.

3.3 Color Transform

In this stage the spectral redundancy is reduced by transforming the components (R, G, and B) into less correlated color space components (like YUV). The conversion RGB to YUV is done using the following equations [13]

$$Y(x,y) = \big((66\,R(x,y) + 129\,G(x,y) + 25\,B(x,y) + 128) \gg 8\big) + 16 \tag{7}$$

$$U(x,y) = \big((-38\,R(x,y) - 74\,G(x,y) + 112\,B(x,y) + 128) \gg 8\big) + 128 \tag{8}$$

$$V(x,y) = \big((112\,R(x,y) - 94\,G(x,y) - 18\,B(x,y) + 128) \gg 8\big) + 128 \tag{9}$$

The following equations are used in YUV to RGB conversion process [13]:

$$C(x,y) = Y(x,y) - 16 \tag{10}$$

$$D(x,y) = U(x,y) - 128 \tag{11}$$

$$E(x,y) = V(x,y) - 128 \tag{12}$$

$$R(x,y) = clip\big((298\,C(x,y) + 409\,E(x,y) + 128) \gg 8\big) \tag{13}$$

$$G(x,y) = clip\big((298\,C(x,y) - 100\,D(x,y) - 208\,E(x,y) + 128) \gg 8\big) \tag{14}$$

$$B(x,y) = clip\big((298\,C(x,y) + 516\,D(x,y) + 128) \gg 8\big) \tag{15}$$

3.4 Chrominance Band down Sampling

Since the chrominance components (U and V) holds only 10% of the whole image information, then these bands are down sampled by 2 to produce the down sampled components (U_d & V_d). This down sampling will cause insignificant subjective distortions in the color image. In the conducted tests, this step was treated as optional (with and without) stage.

3.5 Cubic Bezier Interpolation

CBI is applied on each color sub-band (Y, U_d, V_d), individually, to prune the large scale components of the image bands. It has been accomplished by partitioning each band into a non-overlapped blocks each has predefined length (L_{block} x L_{block}) pixels. Then the following steps are applied:

1. Compute the mean values of each block.
2. Apply cubic Bezier surface for the all pixels belong to each block, such that: For a block has the indexes ($I_x \in [0, N_x\text{-}1]$, $I_y \in [0, N_y\text{-}1]$) take the surrounding adjacent blocks have the indexes [J_x, J_y] to establish the Bezier surface. The range of values of J_x & J_y is selected to be:

$$J_x = \begin{cases} [0,3] & if\ I_x < 2 \\ [I_x - 1, I_x + 2] & if\ 2 \le I_x \le N_x - 3 \\ [N_x - 4, N_x - 1] & if\ I_x > N_x - 3 \end{cases} \tag{16}$$

$$J_y = \begin{cases} [0,3] & \text{if } I_y < 2 \\ [I_y - 1, I_y + 2] & \text{if } 2 \le I_y \le N_y - 3 \\ [N_y - 4, N_y - 1] & \text{if } I_y > N_y - 3 \end{cases} \tag{17}$$

The establishment of cubic Bezier surface could accomplished by applying Bezier approximation twice times, the first is horizontal (i.e., establishing the Bezier curves passing through the centers of adjacent blocks aligned horizontally), and the second is vertical (i.e., establishing the Bezier curves passing through the corresponding vertically aligned points which belong to parallel adjacent Bezier curves.

3. After the construction of Bezier surface, then it is subtracted from the original color bands to compute the residue components (Yr, U_{dr} & V_{dr}).

3.6 Wavelet Transform

In this step, the bio-orthogonal tap 9/7 wavelet filters are applied on residual parts of Y_r, U_{dr} and V_{dr} in separated manners. The transform will decompose each residue color band data to the four known subbands (LL, LH, HL & HH).]

3.7 Scalar Quantization

The progressive scalar quantization was adopted to quantize the coefficients on each wavelet (detail) subbands individually. This step is to reduce the range wavelet coefficients values without making significant subjective distortions in image quality. The reduction in the dynamic values of wavelet coefficient will, consequently, reduce the number of bits needed to represent the coefficients values. The hierarchal scalar quantization process is applied to quantize the coefficients of each subband according to the following equation:

$$Q_s = \begin{cases} Q\alpha^{n-1} & for\ LH\ and\ HL\ in\ n^{th}\ band \\ Q\beta\alpha^{n-1} & for\ HH\ in\ n^{th}\ band \end{cases} \quad (18)$$

3.8 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_r, U_{dr}, V_{dr}). The quadtree method divides a square subband into four equal sized square blocks, and then tests each block to see if meets emptiness criterion [14], in case the tested block is not empty then the search is repeated upon its four daughter quadrants (4x4 blocks). This process repeated, recursively, starting from the whole image and continuing until reaching the smallest block size (i.e., 2x2 block). If it is a non-empty block, then its contents are saved in a buffer beside to the quadtree coding sequence.

3.9 Entropy Encoding

The final process of the proposed system is to compress the data of the non-empty quadtree blocks, which are saved in Seq() buffer. Fig. (3) presents the layout of developed entropy coder; which is designed to efficiently remove the statistical redundancy without significant time consuming and big overhead data.

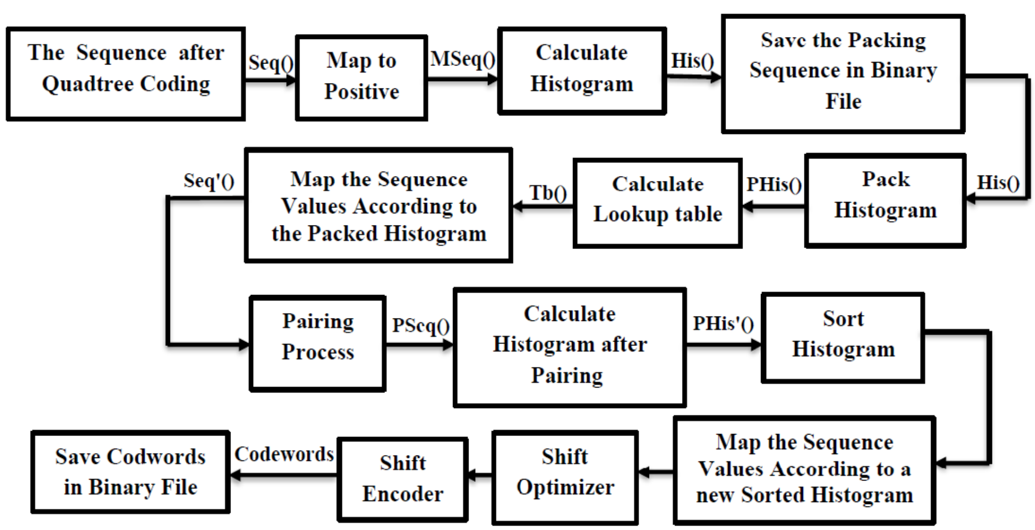

Fig. 3. Entropy encoder

Entropy coding is required after the quad tree step, the produced sequence of coefficients are shift coded, usually the histogram of the incoming sequence shows sharp peak around zero value; this makes shift coding a suitable choice for entropy coding to achieve further compression gain. The introduced enhanced shift coding consists of the following steps:

A. Mapping to Positive

This step aims to convert all elements values of the incoming sequence to positive numbers. This step is useful to avoid coding complexity, due to existence of positive/ negative values, in the next coding steps, such that all negative values are mapped to be odd while the positive values will be even. The mapped elements are produced by applying the following equation:

$$M_i = \begin{cases} 2M_i & if\ M_i \geq 0 \\ -2M_i + 1 & if\ M_i < 0 \end{cases} \qquad (19)$$

B. Do Histogram Packing

Due to the long tails of the histogram of mapped elements values. This long tail is caused to the existence of large elements values, although it has very little probability of occurrence. This long tails cause a significant decrease in compression gain when entropy encoding is applied. Therefore, to address this problem a packing (i.e., shrinking) for the histogram is applied. This histogram packing task is accomplished by using the following algorithm:

```
Set L=0

   For i= 0 to All Histogram Elements
   {  if His(i) > 0 then
      {   L+ +;    MT(i)=1;
          pHis(L)= His(i);    Tbl(i)=L;
      }
      Else MT(i)=0;
   }
```

Where, L is the length of packed histogram, pHis is the histogram array (after packing process), Tbl (i) is a lookup table used to map the positive elements values to packed positive values, and MT( ) is an array of bits, which is required to do the histogram stretching process (during the decompression stage).

C. Map the buffer's elements values to packed values using the lookup table Tbl ().

D. Do Pairing Process

In this step, the most frequent pair of successive values is allocated, then they replaced by single value (i.e., Max+ 1; where M is the highest coefficient value before pairing). The pair replacement steps are the following:

i. Predefine the maximum allowed extended range for a new sequence values.
ii. To determine the most frequent pair, the co-occurrence matrix of the packed sequence is calculated.
iii. Let (MF_1, MF_2) are the elements values of the highest frequent pairs; then replace the pairs (MF_1, MF_2) found in the sequence by single value (=Max+1). After each pairing step increment the Max value by 1. The pairing step should repeated for a number of times till the stopping conditions are fulfilled (that is, if the Max value of sequence is equal to the predefined maximum allowed range or (L−Lp)/(L+1)<0.02) then stop the pairing process). Where L is the length of packed sequence, L_p is the new length after the pairing iteration.

E. Establish the histogram of the produced sequence after pairing step. The histogram is sorted in descending, and an order table, Order (), and saved as overhead information for purposed of decoding operation. The Order () table is used to map the sequence elements values to the newly ordered symbols.

F. As final step, the shift-encoder is applied as entropy encoder due to the following reasons:

i. Owing to its simplicity and efficiency in both encoding and decoding stage.
ii. The size of its corresponding overhead information that needed for decompression process is small (i.e., only two numbers: the length of short and long codewords in terms of bits).
iii. It is a simple type of variable length coding (VLC) schemes. In the VLC methods, short code words are assigned to symbols have higher probability. By this approach, compression efficiency is thus improved by exploiting statistical redundancies [15].

To determine the best two codewords lengths to encode the small and large values of sequence elements, respectively. The optimal values for these two codewords lengths should satisfy

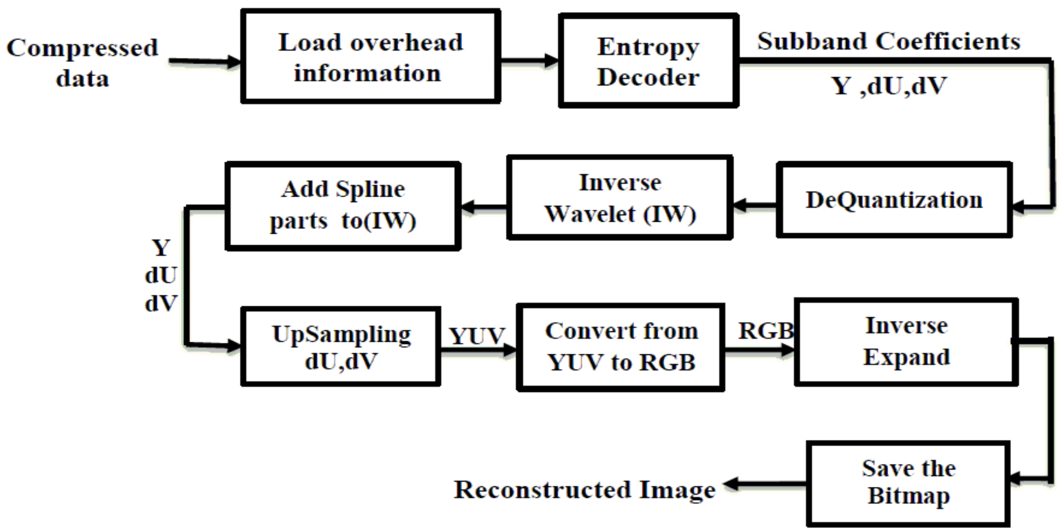

Fig. 4. Decoding process

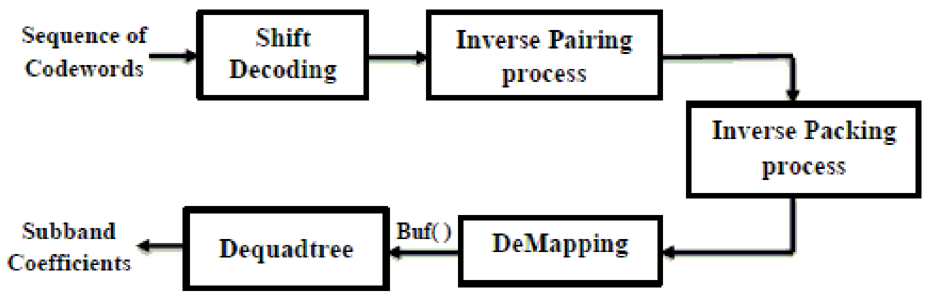

Fig. 5. Entropy decoder

the criteria "they should lead to the minimum total number of bits (T_{Bits}) needed to represent all sequence elements values". A shift coding optimizer is applied using the following equation:

$$T_{Bits} = n_s \sum_{i=0}^{L} His(i) + n_l \sum_{i=2^s-1}^{L} His(i) \quad (20)$$

The values of n_s & n_l represent the length of short codewords and long codewords respectively, that leads to the minimum possible value for T_{Bits}. The array His () represents the histogram array. After determining the proper values of n_s & n_l, then apply the traditional shift coding process to save the output codewords into the binary output file.

To reconstruct the decompressed image, all the encoding steps will be reversed as explained in Figs. (4 and 5).

4. RESULTS AND DISCUSSION

Many sets of tests have been conducted to assess the performance of the proposed image compression scheme in terms of Compression ratio (CR), Peak Signal to Noise ratio (PSNR), Encoding Time (ET), and Decoding Time (DT). The proposed image coding system was implemented using (C# programming language), is working under windows 7 Home premium, The tests have been conducted using laptop computer has processor: Intel ® Core ™ i3-2350M CPU@ 2.30 GHz, RAM: 4.00 GB, x32-based processor. Several parameters were taken into consideration to study the performance of the suggested image compression system. The effects of the following control parameters have been investigated: (i) initial quantization step (Qs) for subbands coefficient (LH, HL, and HH), (ii) the descending rate parameter (α) (iii) Beta multiplication parameter (β), (iv) the block size (L_{block}), (v) the number of wavelet passes (N_{pass}). Table (1) shows the characteristics of the tested image samples. Table (2) presents the adopted default values of the considered control parameters. The effects of each parameter are explored by varying its value while setting other parameters fixed at their default values.

Table 1. The characteristics of the tested image samples

Characteristic	Bitmap image file	
	Lena	Barbara
Bit depth (bit)	24	8
Dimension	256x256	256 x256
Size (KB)	192	192

Table 2. The default values of the control parameters

Parameter	Default value		Range
	Lena	Barbara	
Qs	35	30	[10,40]
α	0.3	0.5	[0.2,0.9]
β	1.9	1.9	[1.1,1.9]
N_{pass}	3	4	[1,4]
L_{block}	6	6	[4,8]

Table (3) lists the compression results with different values of (L_{block}) without applying down sampling on U and V bands. Table (4) shows the corresponding results when U and V bands are down sampled by (2).

Table 3. Tests results on Lena image without applying down sampling

N_{pass}	L_{block}	CR	PSNR (in dB)	Time (in seconds) Encode	Decode
3	4	41	28.78	1.83	0.22
	5	36	30.27	1.68	0.22
	6	34	30.34	1.64	0.27
	7	33	30.34	1.89	0.25
	8	32	28.44	1.67	0.21
4	4	41	28.44	1.6	0.21
	5	37	30.27	1.86	0.27
	6	36	30.34	1.59	0.25
	7	34	30.27	1.77	0.25
	8	35	27.48	1.61	0.24

The results in Table (3) shows that the case L_{block}=6 leads to acceptable compression results in terms of (CR), fidelity measures (PSNR), ET and DT. While, the results in Table (4) indicate that down sampling causes an improvement in compression gain while decreases the PSNR value. Table (5) shows the results when the proposed scheme is applied on Barbara (a gray image), the listed results refer that the case (N_{pass}=4, L_{block}=6) lead to an acceptable compression results in terms of CR and PSNR.

Table 4. Test results on lena image when down sampling was applied

N_{pass}	L_{block}	CR	PSNR (in dB)	Time (in seconds) Encode	Decode
3	4	51	27.52	0.99	0.17
	5	46	28.99	0.96	0.18
	6	44	29.99	0.92	0.19
	7	43	29.04	0.91	0.17
	8	43	27.43	0.9	0.16
4	4	51	27.23	0.96	0.16
	5	46	29.04	0.98	0.17
	6	45	29.04	0.94	0.17
	7	44	29.04	0.97	0.19
	8	45	26.36	0.98	0.16

Table (6) presents the compression results obtained by our proposed method with other existing methods in terms of CR, PSNR.

The efficiency performance of the proposed image coding methods is applied on Lena Image has been evaluated by making comparisons between them and corresponding compression results obtained by applying the compression standard JPEG in term of CR, PSNR ,as shown in Table (7), Fig. (6) shows samples of reconstructed image produced by standard JPEG and the proposed method.

Fig. 6. Samples of reconstructed compressed images

Table 5. Test results on Barbara image

N_{pass}	L_{block}	CR	PSNR (in dB)	Time (in seconds)	
				Encode	Decode
1	4	3.87	30.07	0.96	0.03
3	5	11.13	27.17	0.52	0.04
	6	10.66	28.22	0.57	0.05
	7	10.44	27.98	0.95	0.06
4	5	12.08	27.96	0.49	0.06
	6	12.05	28.10	0.49	0.04
	7	11.86	28.05	0.53	0.04

Table 6. Comparison with previous studies

Author	Method	Image	CR	PSNR (in dB)	Details	
					Bit depth (in bit)	Size (in KB)
[16]	The Bio-orthogonal Tap 9/7 Wavelet Filters Applied on Photographic Images (monochrome and color).	Lena	12.05	26.89	24	64
		Barbara	12.46	28.78	8	64
[17]	The Combination of Integer Wavelet Transforms (IWT) and Predictive Coding have been Used for Lossless Image Compression.	Lena	8.0	Not Mention	8	192
		Barbara	7.0	Not Mention	8	192
[18]	The Color Transform (Y,C_b,C_r) followed by Wavelet (Tap 3/5) Transform, Pyramid Quantization, Bitmap Slicing Coding, & Finally huffman coding have been used to Compress Color Images.	Lena	25.21	33.1	24	514
Proposed Method	Cubic Bezier Interpolation, Tap 9/7 Wavelet, Quadtree and High Order Shift Coding have been applied to Compress Color Image.	Lena	44.00	29.99	24	192
		Barbara	12.05	28.10	8	192

Table 7. Comparison between the compression results of JPEG standard coders and the proposed scheme used to encode Lena color image

Tested image	Method	Controlled parameter					CR	PSNR
Lena	**JPEG standard**	**Quality**						
		10 %					24.77	30.46
		20 %					23.35	30.77
		30 %					21.21	31.18
		40 %					21.59	31.60
		50 %					17.45	32.15
		60 %					15.48	32.72
		70 %					12.97	33.49
		80 %					10.32	34.56
		90 %					6.9	39.48
	Proposed scheme with down sampling	N_{pass}	L_{block}	β	α	Qs	CR	PSNR
		3	7	1.9	0.7	10	28.47	30.58
		2	6	1.4	0.4	20	28.25	30.61
		3	5	1.9	0.6	10	24.85	31.01
		3	5	1.6	0.4	20	34.44	30.03
		3	6	1.9	0.4	20	34.55	30.02
		4	7	1.8	0.4	20	34.93	30.02
		4	6	1.7	0.4	20	35.58	30.02
		4	5	1.6	0.4	20	36.23	30.05
		4	5	1.7	0.4	20	36.83	30.01

5. CONCLUSION

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

- The use of CBI had improved the compression performance (i.e., increase the compression gain while preserving the image quality).
- The increase in quantization step causes an increase in compression ratio and a decrease in PSNR value.
- As a future work the developed system can be improved by applying the first order polynomial on the small areas of residue component (i.e., after subtracting the cubic Bezier from the image). In order to prune the local smoothing components and getting better compression gain.

COMPETING INTERESTS

Although the attained compression gains of the proposed lossy image compression scheme is outstanding; the compression gain could further improved by introducing extra coding stage to prune the local low-frequency. For example the use of polynomial representation on the residue component may improve the compression performance.

REFERENCES

1. Reny CL, et al. A Survey on hybrid image compression techniques for video transmi-ssion. International Journal of Electronics and Communication Enginee-ring. 2013;6(3):217-224.
2. Parmar C, Pancholi KA. Review on image compression techniques: Journal of Information Knowledge and Research in Electrical Engineering. 2013;2(2):281-284.
3. Bindu K, Ganpati A, Sharma AKA. Comparative study of image compression algorithms: International Journal of Research in Computer Science. 2012; 2(5):37-42.
4. Johnsen, ST, Standeren M. Evaluate multiple description coding as an image processing method for transferring information in error-prone networks with low transmission rate, related to quality, bit rate and file size. M.Sc. Thesis, Faculty of Engineering and Science, Agder University College, Norway; 2005.
5. Goyal R, Jaura J. A review of various image compression techniques. International Journal of Advanced Research in Computer Science and Software Engineering. 2014;4(7):708-710.
6. Muthaian R, NeelaKantan K, Sharma V, Arora A. Image compression and reconstruc-tion using cubic spline interpolation technique. American Journal of Applied Sciences, Nov. 2008;5(11):1562-1565.
7. Thayammal S, Selvathi D. A review on transform based image compression techniques. International Journal of Engineering Research & Technology (IJERT), October. 2013;2(10):1589-1596.
8. Thannoon BN, George LE. Image compression using hybrid coding methods. Al-Nahrain University Journal for Science. 2006;9(2):64-68.
9. Lin TC, Chen CW, Chen SH, Truong TK. Near lossless medical image compression using JPEG-LS and cubic spline interpolation. SPIE Proceeding, Optics and Photonics for Information Processing. 2008;7072(2):1-7.
   DOI: 10. 1117/12.794906.
10. George LE, Sultan, BA. The use of bi-orthogonal wavelet, 2d polynomial and quadtree to compress color images. Signal Processing, Image Processing and Pattern Recognition (SIP-2011), Communications in Computer and Information Science (CCIS), Springer-Verlag Berlin Heidelberg. 2011;260:379-390.
    DOI: 10.1007/978-3-642-27183 -0-40
11. Sharmila K, Kuppusamy V. An efficient image compression method using dct, fractal and run length encoding techniques. International Journal of Engineering Trends and Technology (IJETT). 2014; 13(6):287-290.
12. Khan M, Ohno Y. A hybrid image compression technique using quadtree decomposition and parametric line fitting for synthetic images. Advances in Computer Science and Engineering. 2007; 1(3):263-283.
13. Available:http://msdn.microsoft.com/en-us/library/ ms893078.aspx (April, 2004).
14. Veenadevi SV, Ananth AG. Fractal image compression using quadtree decomp-osition and huffman coding. Signal & Image Processing an International Journal (SIPIJ). 2012;3(2):207-212.

DOI: 10.5121/sipij. 2012.3215.
15. Joshi MA, Raval MS, Dandawate YH, Joshi KR, Metkar SP. Image and video compression fundamentals, techniques, and applications: Chapman and Hall/CRC, ISIN 13:978-1-4822-2823-6; 2015.
16. Krishnaiah GC, Jayachandraprasad T, GiriPrasad MN. Efficient image compression algorithms using evolved wavelets. International Journal Systems and Technologies. 2011;4(2):127-146.
17. Gupta K, Verma RL. Minimum entropy based Lossless image compression using predictive coding and integer wavelet transform. International Journal of Engineering Science and Innovative Technology (IJESIT). 2013;2(4):603-612.
18. George LE, Al-Abud BQ, Mohammed FG. Image compression based on biorthogonal wavelet transform: Journal of Al-Nahrain University. 2007;10(2):178-186.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/11224