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Correlated Block Quad-Tree Segmented and DCT based Scheme for Color Image Compression

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Abstract

Background/Objectives: This paper presents a color image compression method to increase the compression ratio without affecting the original scene by noise or distortion. **Methods/Analysis:** In this paper an attempt to minimize data loss without highly affect the compression ratio by employing low lossy rate quad-tree compression technique to increase the correlation between pixels that will enhance DCT results and also compress the data before DCT phase, using Quantization and entropy encoders such as run length encoding and shift encoding will further compress the image. **Finding:** For conducted six different visual information images, the Compression Ratio (CR) results of the proposed method on average to be around 1:29 of the size of the original image, more compression ratio can be achieved by increasing the compression levels, this high compression ratio is considered a best ratio compared with the achieved Peak Signal to Noise Ratio (PSNR) of the decompressed-compressed image. **Application/Improvements:** This compression system can be used in Storing or Transforming Color Images due to its high compression ratio while the noise and distortion still as minimum as possible.

Keywords: Color Image Compression, Discrete Cosine Transformation, Quad-Tree, Quantization, Run Length Encoding, Shift Encoding

1. Introduction

Data transmission and Data storing, the first would suffer in transferring rate specially if the data size is large which will require lot of time to transfer little amount of data, while the second may suffer the lack of storage capacity for the same reason. Data compression is the only solution to such complexity. Data compression can be applied to any type of data but with boundaries. Text data and application data should not suffer a data loss after recovery phase such type of compression called lossless compression, while multimedia Data (images, audio and video) can be compressed using lossy or lossless compression techniques[1,2].

Using a lossless compression technique will guarantee data integrity at the expense of compression ratio, while lossy technique will provide the opposite the more compression ratio achieved the more data loss occur, Numerous of lossy compression techniques has been introduced to minimize the date loss and increase compression ratio[3].

The rest of the paper is organized into 6 Sections, some of the related works are illustrated in Section 2, Section 3 a brief mathematical background of the used techniques, Section 4 a full description of the proposed system along with the achieved results in Section 5, finally the conclusion is pointed out in Section 6.

2. Related Work

Literature review was conducted to cover some of the relevant works, and provide an overview of the previous important works in compression approaches. In[4], proposed a method that used an appropriate organization of DCT coefficients similar to that of wavelet characteristics which can be achieved such as energy compaction, cross-sub band similarity, decay of magnitude across sub band, etc. In[5], proposed a fractal coding technique on DCT

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to perform a Fractal image compression. In[6], proposed a coder based on quad tree set partition for DCT. In[7], introduce a block-based Discrete Cosine Transformation technique in which the first transform may not be vertical or horizontal one, instead it may follow other directions, then the resulting coefficients are arranged in a more appropriate form for the second transform. In[8], proposed that instead of using an eight by eight blocks and then the 2D DCT technique he divide the image into trapezoid or triangular blocks depending on the objects shapes. In[9], proposed an automatic image compression method by modifying the gamma value of each pixel with the use of many encoding techniques together with DCT.

3. Mathematical Background

3.1 DCT

Discrete Cosine Transformation is the most widely used compression technique for images and audios. DCT is a Fourier-based transform using cosine function only since only few number of cosine functions is needed to represent a signal compared to sine. Several types of DCT has been introduced each serves different applications; the most common type is DCT-II which sometimes called the DCT only[10,11].

DCT 2-Dimension's Equation:

$$c(u,v) = d_{(u)}d_{(v)}\sum_{x=0}^{N-1}\sum_{x=0}^{N-1} f(x,y)\cos\frac{(2x+1)u\pi}{2N}\cos\frac{(2y+1)v\pi}{2N} \quad (1)$$

Inverse of DCT 2D equation:

$$f(x,y) = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} d_{(u)}d_{(v)}c(u,v)\cos\frac{(2u+1)u\pi}{2N}\cos\frac{(2v+1)v\pi}{2N} \quad (2)$$

3.2 Quad-Tree

The quad-tree is a segmentation technique based on hierarchical partitioning that partition an image into blocks based on the shown structure in Figure 1. top-down scanning approach is used for the simplicity and flexibility[12].

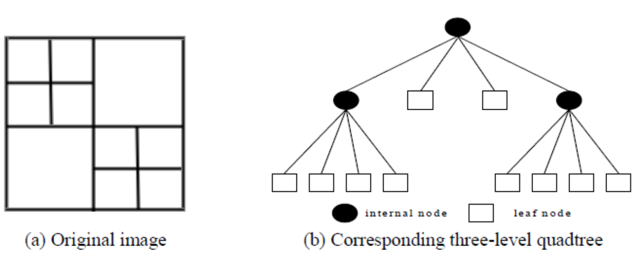

Figure 1. Quad-tree structure.

Block partitioning classifier is employed to determine the block type. Using some statistical information such as block variance, averaged block absolute error, and so on, to determine the block homogeneity. By choosing adequately controlling thresholds, different statistical measurements can be employed to control the quad-tree segmentation process[13,14].

This segmentation can be employed as a compression technique, using the same statistical information; a single value can replace a block, which can achieve a very high compression ratio with a small rate of data loss.

3.3 Run Length Encoding

Run Length Encoding (RLE) is a lossless compression technique, very useful when the data contains a run of similar values, the longer these runs the better compression ratio achieved, the technique works by calculating the length of each run, and replace these runs with 2 values only the length and the run value[15]:

{2,5,5,5,5,3,3,4,4,4,4,4,4,7,7,7,7,7,7,1} >
{1:2,4:5,2:3,6:4,6:7,1:1},
CR=20/12=1.67

3.4 Shift Encoding

Shift Encoding is a lossless technique to minimize the representing (code) of a fixed size pattern to a less sufficient size, which will yield a less size to represent the data.

This can be done by first calculating the best size for representing the data, then using a shifting method to assign a different smaller code for each character, number…etc[16].

3.5 Quantization

Quantization is a lossy compression technique based on reducing ranges of value to a smaller fit range, applying this technique on non-RGB color space is better because human vision sensitivity to luminance (intensity of light) is greater than chrominance (color)[17].

3.6 Peak Signal to Noise Ratio

PSNR is a ratio of noise to the maximum signal power; PSNR is a good estimator to measure the strength of the decoders[18].

PSNR can be computed depending on MSE by the following Equation:

$$psnr = 10log_{10}\left(\frac{MAX^2}{MSE}\right) \quad (3)$$

Where max represent the maximum value of the signal (image pixel).

And MSE can be computed by the following Equation[19]:

$$e = \frac{1}{mn}\sum_{i=0}^{m}\sum_{j=0}^{n}(x_{(i,j)} - x'_{(i,j)}) \quad (4)$$

The acceptable value of PSNR ranges up from 30 db, the higher it's the best results achieved.

3.7 Compression Ratio

Is the measurement of compression strength by taking the ratio of the compressed image size to its original image size[20]. CR can be computed by the following Equation:

$$CR = \frac{original\ size}{compressed\ size} \quad (5)$$

4. The Proposed System

The proposed system consists of two units encoding and decoding units:

4.1 The Encoding Unit

The proposed compression technique workflow starts by converting the image color space from (RGB) to a more suitable color space such as (YUV), the reason for such conversion is to minimize the visual data loss visibility, YUV consist of one luminance component (Y) and two chrominance components (U, V), the YUV encoders takes human perception into account, enabling lossy compression to be more efficiently masked than using the RGB image representation. Figure 2 shows the steps of proposed encoding system.

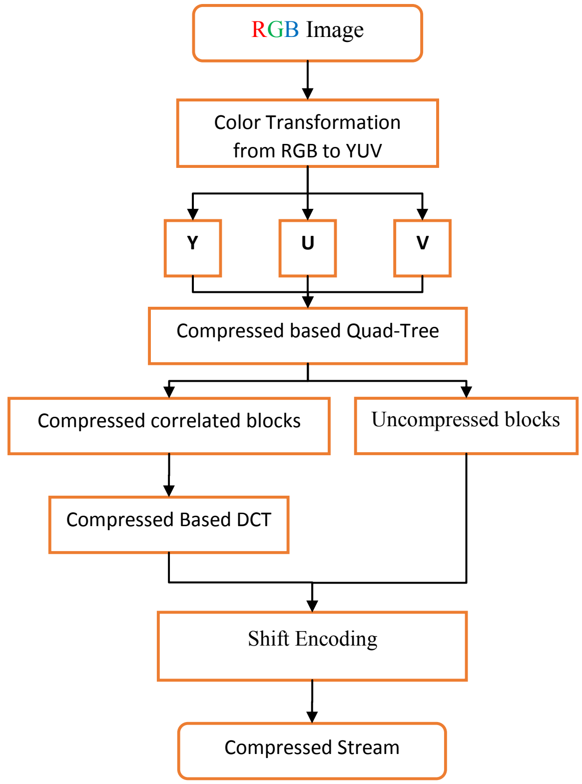

Figure 2. Proposed encoding system.

4.1.1 *Compressed based Quad-Tree*

After the color space changes Y, U and V component passes through a quad-tree phase, in which each band is subjected to dividing into quadrant, till a uniform quadrant reached.

In proposed system the uniform quadrant is a segment in which all values are different by a very small amount (max difference (MaxDiff) <=1,2) if the quad tree is lossy, or the same if it lossless (MaxDiff = 0). Figure 3 shows the details of compressed method based Quad-Tree.

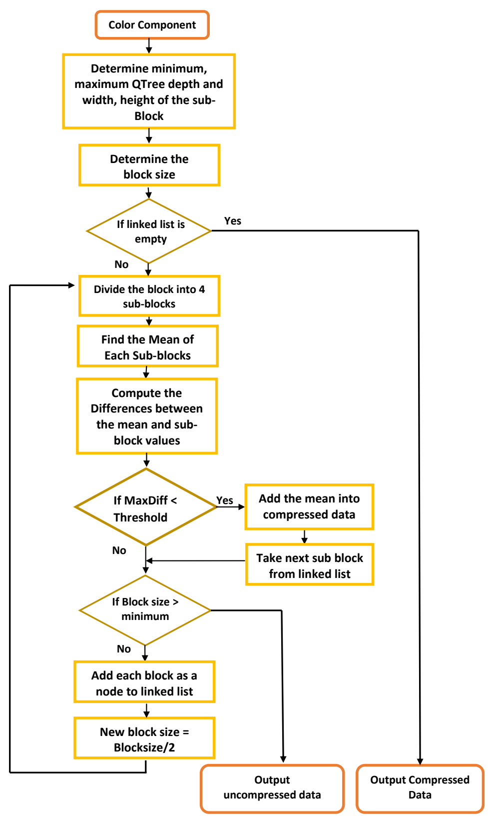

Figure 3. Compressed based quad-tree.

4.1.2 Compressed based DCT Scheme

The DCT applied on the compressed date output of each component that has been resulted from compressed base quad-tree using the following steps:

Step 1: Partitioning the output into 8×8 blocks as the input to the DCT.

Step 2: After the partitioning each block is transformed by 2D DCT transformation. The resulted blocks are quantized using the following Equation:

$$Qstep = Q_{\downarrow}0(1-\alpha(\mathrm{u}-\mathrm{v}) \quad (6)$$

$$F_Q(u,v) = Round\left(\frac{f(u,v)}{Qstep}\right) \quad (7)$$

The two values: Q0 and α, specifies the strength of the quantizer, the higher they are the higher quantization level achieved.

Step 3: The first element in each block called the DC coefficient the rest are the AC coefficient. DC coefficients will be collected in an array, on the other hand the AC coefficients will undergo a Zig-Zag Scanning, and the zigzag scanner will arrange the 2D blocks into 1D according to the following order: (Figure 4).

The zig-zag scanner will enhance the outcome of the Run Length Encoding operation followed.

Step 4: The RLE is a simple compression technique in which a sequence of data is stored as a data value and its run length, this operation is very efficient after a zigzagged quantized data since a long run of zeroes will be substituted to only a data value (0) and the length of the zeroes.

Step 5: On the other hand, the DC coefficients will undergo a modulator function, the functionality of the modulator is to reduce the values of the DC coefficients by subtracting each value from its preceding one, and this will enhance the outcome of the subsequent operations.

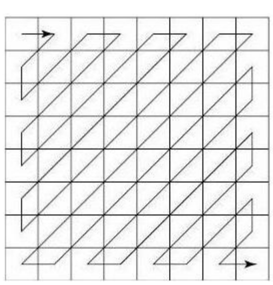

Figure 4. Zig-zag order.

$$d_i = DC_{i+1} - DC_i \quad (8)$$

$d_o = DC_o$

Step 6: The resultant value ranges in both positive and negative, one prerequisite for the shift encoding phase is that the values should all be in positive, to achieve that a mapping to positive function will be used, the function work as follow:

$$X_i = \begin{cases} 2X_i & if\ X_i \geq 0 \\ -2X_i - 1 & if\ X_i < 0 \end{cases} \quad (9)$$

Now the uncompressed date is ready for the Shift encoding phase, shift encoding phase implementing following these steps[15]:

- Determine the optimal value for the shortest code word length (nbl) and the longest one (nbs) using the following Equation:

$$nbl = log_2 X \quad (10)$$

Where X is the largest value in the data

- Compute *nbs* using the following Equation:

$$nbs = n_s \sum_{i=0}^{l} Histogram(i) + n_l \sum_{i=nl}^{l} Histogram(i) \quad (11)$$

- Perform the entropy encoding and save the *nbl* and *nbs* values along with the compressed data stream. The final result along with a set of information represents the compressed image data (Figure 5).

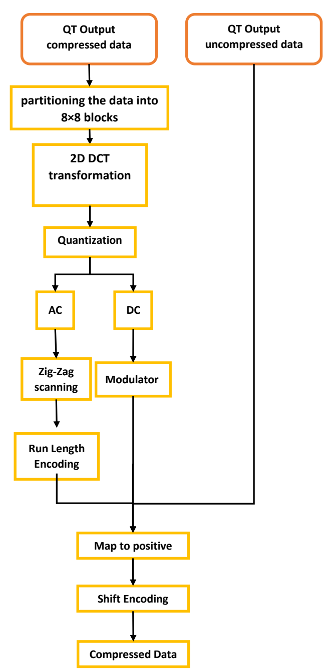

Figure 5. Compressed based DCT scheme.

4.2 The Decoding Unit

The compressed data file contain all the information needed along with the data to decompress the image, the operation starts by extracting the information such as the size, minimum code words and maximum code words for each component.

The decompression process is the reverse of the entire compress process, that is; starts by shift decoding as the inverse of shift encoding phase. Then an inverse to mapping to positive function applied on the result using following Equation:

$$X_i = \begin{cases} \frac{X_i}{2} & if\ X_i mod2=\mathbf{0} \\ \frac{-X_i+\mathbf{1}}{2} & if\ X_i mod2\neq\mathbf{0} \end{cases} \quad (12)$$

Using the extracted information, the result is divided into 2 parts the first represent the compressed data of the compression Quad Tree Phase, while the second is the uncompressed data.

The first part undergo a IDCT transform starts by a run length decoding, then the inverse of quantization function, passing through the IDCT equations

Now the QT compressed data along with the QT uncompressed data are ready for the Quad tree decompression to retrieve the YUV components. A conversion back from YUV to RGB color band Capable of recovering the original image.

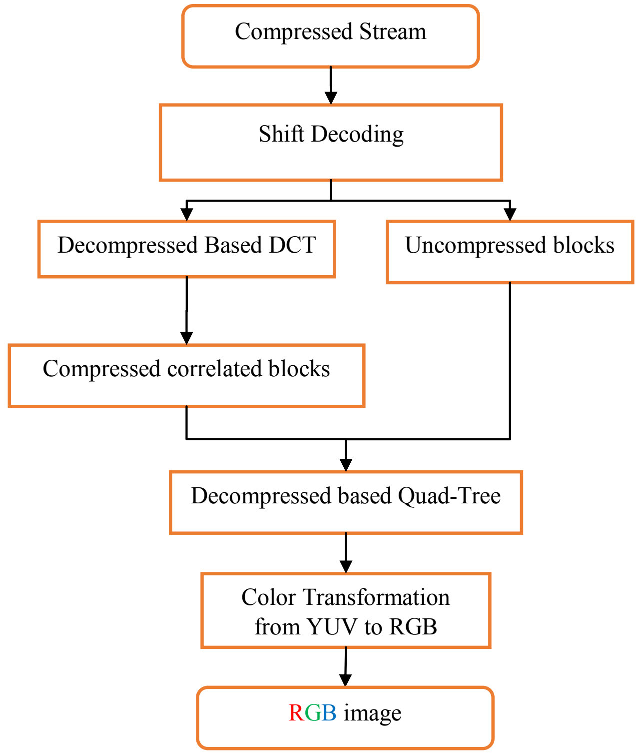

Figure 6. Proposed decoding system

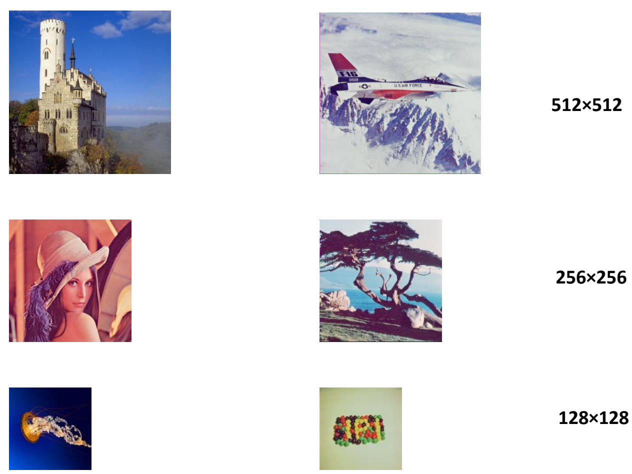

Figure 6. Test images.

5. Experimental Result

Various tests have been implemented to evaluate the performance of the proposed algorithms. The results of implemented the two hybrid compression schemes (i.e., Quad-Tree and DCT) are presented and discussed. Six RGB bitmap images ("Liechtenstein", "Jet-plane"," Lena", " Tree ", "Jellyfish" and "jelly-beans") have been used. These images have different sizes and different visual properties, such as a natural scene, different colors, containing lot of edges and containing high correlated sections. Figure 6 shows these six test images.

The compression scheme and the retrieved images are examined using various fidelity measures; among them is the PSNR which is used to express the fidelity of revealed images. The listed results in Table 1 illustrate the CR and PSNR after performed proposed system with different cases of Max difference (MaxDiff) condition for compressed based Quad-Tree and different values for the quantization parameters (Q_0 and α) yield different results for each experiment.

It is notice that the higher threshold gives a higher compression ratio at the expense of the quality (PSNR). Also, the image size, on average, it fell to about 1: 29 from the original image size under consideration that the quality of the image must be at an acceptable level (i.e., greater than 30 dB).

Figures 7 and 8 show the CR and PSNR for three images respectively after applying proposed Quad-Tree

Table 1. Results after encoding on 6 different size and visual images

MaxDiff	quantization		Jellyfish 128*128		Jelly Beans 128X128		Lena 256*256		Tree 256X256		Lichtenstein 512*512		Jet Plane 512X512	
	Q0	α	CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR	CR	PSNR
0	1	1	3.24	35.6	3.42	33.7	2.573	36	1.9	34.55	3.799	37.5	3.14	35.15
		2	4.58	33.5	4.73	32.24	3.75	33.6	2.7	32.6	5.47	35.1	4.37	33.98
		3	5.68	31.75	5.77	30.99	4.78	32.23	3.5	31.21	6.9	33.4	5.84	32.34
		4	6.69	30.96	6.78	30	5.67	31.1	4.2	30.26	7.8	32.34	6.87	31.46
		5	7.49	30	7.82	29.06	6.46	30.34	4.8	29.3	9.47	31.27	7.92	30.62
3	1	1	6.06	34.53	5.88	36.2	4.68	35.96	2.65	34.8	6.77	37.46	6.07	36.18
		2	7.89	33.78	7.7	33.98	6.49	34.07	3.79	32.33	9.39	35.43	8.52	34.6
		3	9.76	32.7	9.23	32.88	8.3	32.76	4.62	31.67	11.6	33.5	10.66	33.2
		4	11.2	31.1	10.87	31.43	9.92	31.66	5.52	30.47	14.08	32.54	12.9	32.27
		5	12.6	30.47	12.5	28.16	11.4	30.9	6.39	29.56	16.3	31.66	14.8	31.51
	2	1	8.44	32.35	8.03	33.81	7.02	34.26	3.87	32.8	9.9	35.23	9.04	34.14
		2	11.6	30.8	11.38	31.22	10.3	31.75	5.75	30.4	14.6	32.42	13.43	32.04
		3	14.56	28.88	14.41	28.8	13.6	30.3	7.65	28.8	19.1	30.85	17.29	30.647
		4	17.16	27.77	17.44	28.16	16.52	29.25	9.34	27.8	24	29.77	21.5	29.68
		5	19.72	26.6	21.11	27.41	19.22	28.6	10.88	27.08	27.7	29.05	25.15	28.97
	3	1	10.47	32.02	10.08	30.89	9.12	32.69	5.07	31.3	12.86	33.37	11.86	32.81
		2	14.89	29.13	14.66	28.5	14.06	30.17	8	28.44	20.16	30.69	17.86	30.5
		3	18.89	27.04	19.49	27.07	18.3	28.8	10.56	27.3	26.36	29.32	23.99	29.21
		4	23.12	26.34	24.55	26.15	22	27.88	13.03	26.49	32.59	28.49	28.56	28.34
		5	27.08	25.19	29.06	25.56	25.8	27.3	14.9	25.8	38.5	27.88	33.1	27.72
5	1	1	7.64	34.9	7.81	33.6	6.77	35.54	3.45	34.34	8.61	36.6	8.96	35.92
		2	9.62	33.89	9.03	32.31	9.17	34.1	4.51	33.04	11.64	35.19	12.07	34.78
		3	11.75	33.09	10.69	31.97	11.23	33.06	5.62	31.8	14.16	33.84	14.7	33.67
		4	13.35	31.09	12.58	31.1	13.26	31.93	6.65	30.68	17.08	32.7	17.5	32.7
		5	15.05	31.01	14.23	29.6	15.55	31.15	7.66	29.8	19.59	31.78	19.95	31.95
	2	1	10.28	33.7	9.42	34.25	9.59	34	4.83	32.9	12.17	35	12.66	34.63
		2	13.8	31.7	13.06	30.97	14	31.76	6.9	30.55	17.65	32.3	18.1	32.61
		3	17.1	29.75	16.46	29.27	18.15	30.54	9.22	29.07	22.97	30.98	23.17	31.22
		4	20	28.86	19.9	28.59	22.12	29.45	11.24	28.03	28.8	30	28.79	30.19
		5	22.54	27.68	23.8	27.38	26.55	28.4	13.2	27.28	34.1	29.28	33.7	29.52
	3	1	12.67	32.84	11.68	31.86	12.37	32.78	6.13	31.56	15.59	33.47	16.08	33.06
		2	17.77	29.7	16.91	29.14	18.6	30.46	9.57	28.98	23.6	30.9	24.33	31.09
		3	22.16	28.15	22..47	27.54	25.11	28.97	12.8	27.6	32.36	29.47	32.04	29.71
		4	27.33	26.72	27.9	26.8	30.25	28.34	15.78	26.73	40.2	28.5	39.25	28.85
		5	32.42	25.8	33.99	25.78	35.79	27.76	18.35	26.12	47.97	27.99	47.05	28.29
10	1	1	11.39	31.1	10.06	32.41	13.08	33.01	5.96	31.24	13.17	34.47	17.03	33.87
		2	13.9	30.85	12.19	31.93	17.23	32.56	7.83	30.67	17.49	33.87	21.67	33.48
		3	16.7	30.34	14.38	32.89	20.34	31.98	9.188	29.84	20.88	33.11	26.1	32.95
		4	18.97	29.89	16.64	30.38	23.43	31.48	10.44	29.06	24.02	32.37	29.88	32.37
		5	20.9	29.21	18.73	30.09	27.2	30.94	12	28.39	27.87	31.65	33.44	31.79
	2	1	14.88	33.32	12.65	31.86	17.96	32.59	8.09	30.11	18.19	33.76	23.12	33.61
		2	19.46	31.28	17.19	30.28	24.76	31.36	10.95	28.99	25.32	32.25	30.62	32.43
		3	23.67	29.82	21.12	29.7	31.13	30.54	13.7	27.52	32.21	31	38.89	31.38
		4	27.63	28.84	25.54	27.57	37.79	28.8	16.67	26.5	39.6	30	46.44	30.52
		5	31.1	27.79	29.9	28.14	45.1	28.97	19.58	25.79	48.2	29.44	53.99	29.88
	3	1	17.78	32.38	15.5	31.32	21.96	31.99	9.9	29.7	22.75	32.94	27.63	32.92
		2	24.6	30.27	21.69	29.86	31.5	30.23	13.99	27.55	33.01	30.88	39.66	31.31
		3	30.68	28.18	28.39	27.77	42.22	29.41	18.55	26.17	45.45	29.68	51.26	30.17
		4	37.23	27.11	35.1	27.13	51.84	28.57	23.4	25.23	56.7	28.86	62.68	29.4
		5	44.48	26.16	43.07	26.36	61.34	27.85	28.03	24.53	68	28.33	75.17	28.72

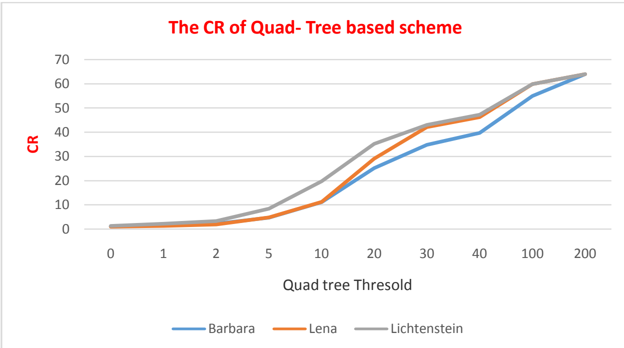

Figure 7. The CR for various maxdiff values using quad-tree based scheme.

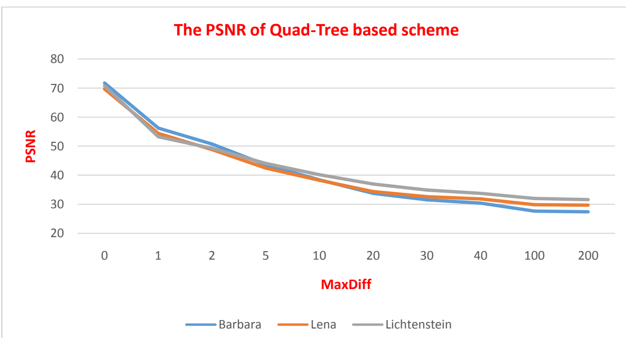

Figure 8. The PSNR for various maxdiff values using quad-tree based scheme.

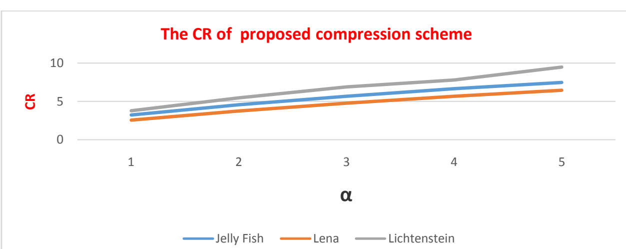

Figure 9. The CR for various α values using proposed compression scheme.

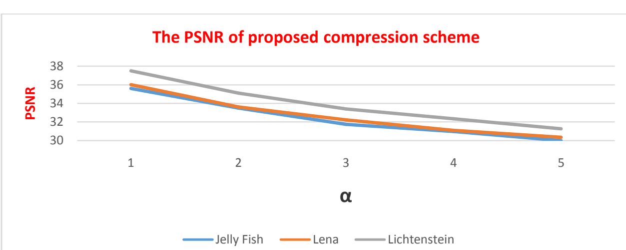

Figure 10. The PSNR for various α values using proposed compression scheme.

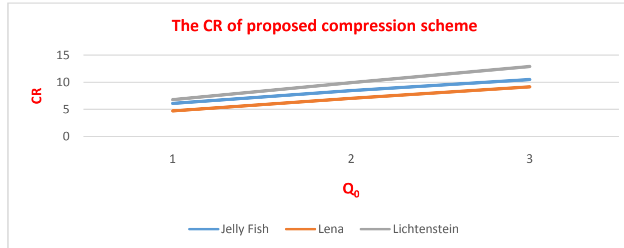

Figure 11. The CR for different Q0 values using proposed compression scheme.

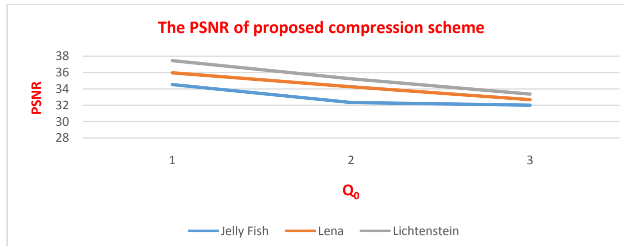

Figure 12. The PSNR for different Q0 values using proposed compression scheme.

based scheme with different max difference values (MaxDiff).

Figures (9, 10, 11 and 12) show the CR and PSNR for three images respectively after applying proposed compression scheme (i.e., Quad-Tree and DCT based schemes) with various α and Q_0 values.

6. Conclusion

In this paper a novel compression scheme for color image based on Quad-Tree segmented and DCT based methods has been proposed. In the proposed system, quad tree is employed as a compression technique before the DCT phase; this method was successful in term of compression and decoding strength. The selecting values of quad tree threshold (Max-Diff) and quantization steps (i.e., Q_0 and α) have a great impact on the results as shown earlier in Section 5. Through the design, implementation and test phase several notes have been recorded:

- Compression rates and its related peak signal to noise ratio is very good compared to other related works.
- Quad tree enhanced DCT outcome, since DCT better works with uniform segment and quad tree works to divide the image data into correlated and uncorrelated, that can be noticed in Lena image results, achieving a

compression ratio of 31.5 with PSNR of 30.23 is a very good result to such an edge full image.

- Different compression parameters made different results.
- The results listed in Table 1 show that the size of images, on average, were reduced to be around 1:29 of the size of the original images. The CR is selected under the consideration that the quality of the image should be at acceptable level.

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