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Fast and efficient lossless encoder in image compression with low computation and low memory

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Abstract

This research focuses on frequency-based lossless new encoding technique with low computation and low memory scheme. This encoding technique doesn't require, any table similar to Huffman and Golomb Rice encoder, and doesn't take high computation time like an arithmetic encoder. For better comparative results, nearly 200 standard images were tested with the proposed encoder and their results were compared with the standard encoders. Based on the analysis of results reported in the experimental part, the proposed scheme in Discrete Cosine Transformation (DCT) achieves a high Compression Ratio (CR) of 97.68 %, Bits Per Pixel (BPP) of 0.19, Peak Signal To Noise Ratio (PSNR) of 27.62 dB for pepper image, CR of 98.65%, BPP of 0.11 and PSNR of 29.24 dB for house image, CR of 98.58 %, BPP of 0.11, PSNR of 30.59 dB for pepper image, CR of 98.37%, BPP of 0.13, PSNR of 31.37dB for house image in Discrete Wavelet Transformation (DWT) than compared to other encoders. It consumes less computation time to attain superior CR with a better quality of reconstructed picture than DCT based Huffman, Golomb-Rice (GR) coder and Low Complexity, Low memory Entropy Coder (LLEC), DWT based Arithmetic, GR code, LLEC.

1 | INTRODUCTION

In the modern world, data is wealthier and more informative in the digitized format. With the rapid growth of the digitized image, image processing [1, 2] is a vital part of data transmission and data storage. It consumes a very huge volume of data. To minimize the volume of bits to signify the image, compression techniques assign the minimum range of bits for each information. It reduces the band's cost of sending the image through a network with different formats of image. The most popular image formats are JPEG and JPEG-2000 [3, 4], which are a prominent compression standard. There are broadly applied in numerous image applications and software. Basically, image compression is accessed into lossless and lossy scheme of compression. The decoded image is equivalent to the tested image in lossless compression, and there is no loss of data. These techniques are widely used in medical applications to identify cancer detection, bone morrow identification etc., Huffman encoding,

run-length coding, arithmetic encoding, and differential pulse code modulation (DPCM) are some of the lossless techniques in image compression. Content-based image compression LOCO-1 [5], LampelZiv code [6], Golomb–Rice (GR) code [7], JPEG lossless (LS) [8,9], and CALIC lossless coding [10] are some schemes that are reported for lossless image compression. Lossy compression is used to increase the CR to minimize the number of bits to signify the decoded image. The data is lost in the lossy techniques and not equivalent to the input image. Transform coding and fractal compression [11], sub-band coding [12], predictive coding [13], and vector quantization [14], JPEG, and JPEG2000 are well known lossy compression techniques. Image compression involves four stages; namely, transformation, quantization, encoding, and decoding. A mathematical function called transformation is applied to the actual input image to reduce their correlation between the pixels, which makes the image operations are easier to solve than the original image. There are various transformations used in image

compression named as follows; Karhunen–Loève transformation (KLT) [15] is the optimal transformation technique and keeps much energy as possible in the result with few coefficients. Walsh Hadamard transformation (WHT) [16] is the fastest data compression method since it requires only addition and subtraction operations. Discrete cosine transformation (DCT) [17] is a great energy compaction and popular blocking transformation technique used in image processing. Due to the blocking artefacts and the increasing compression ratio, discrete wavelet transformation (DWT) [18] is used. It involves multi-resolution compression and higher computation complexity when compared to other transformations. Quantization is a high compression technique that reduces the required bits to represent the decoded image. Generally, it reduces the precision of the transformed coefficients more and more in which less number of non-zero coefficients are obtained. Two types of quantization techniques are used in image compression, namely, scalar and vector-based quantization. Scalar quantization (SQ) is the most commonly used simple quantization, denoted as $y = Q(x)$. Quantization function Q maps the 'x' input value to output value 'y'. It considers one sample at a time. Each transformed coefficient is quantized by applying the quantization table. Krishnamoorthy [19] et al. have presented a new integer compression coding technique using SQ with orthogonal polynomials transformation to give good CR. To improve the performance of SQ and lower the average distortion, vector quantization considers the whole vector of data, then applies a look-up table to extract an approximation of the coded vector. Shen et al. [20] have presented a vector quantization (VQ) based compression technique to enhance the standard of vector quantization compressed image and produce lossless compression. Some of the vector quantization techniques are tree-structured vector quantization [21], side match vector quantization (SMVQ) [22], and finite state VQ [23]. After applying quantization, the high-frequency coefficients or alternating current (AC) near to the first element in DCT, called direct current term are almost zero, when divided by the larger quantum values. A major drawback of this technique is the low eminence of the reconstructed image which is known as artefacts. In the final stage, the entropy coding converts the transform coefficients into the binary bitstream and reduces the coding redundancy. Huffman coding and arithmetic coding are the two popular entropy coding techniques utilized in image compression. Huffman encoding is a lossless technique based on statistical and variable-length coding. It allocates lesser codes for more frequently used characters and less frequency takes larger codes for compressing the image and reduces the storage. It refers to the Huffman table to generate bit codes to the source character. So, it takes extra memory to process encoding and decoding. In arithmetic coding, each source symbol can be used to represent the range of bits per character. It differs from an alternative type of encoder reminiscent of Huffman's writing. It divides the input values into part symbols, then it replaces every symbol with a lower code. Due to this process, the encoding part takes high computation time to generate bit codes to the input symbols. Both these techniques are used in lossy and lossless compressions based on the usage of quantization. These encoders take high compu-
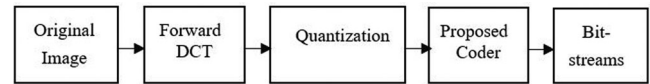

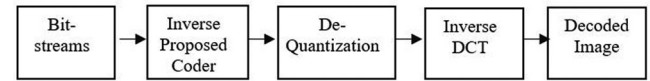FIGURE 1   Encoding process with proposed coder

FIGURE 2   Decoding process using the reverse process of proposed coder

tation time and additional memory requirements to achieve the compression due to reference to the tables or codebooks. To solve this issue, Debin Zhao et al. [24] stated an entropy coder called low complexity and low memory entropy coder (LLEC) that can compress the image with high CR. It takes minimum computation time and a low amount of memory. GR coding technique is a variable-length code like Huffman and it consists of two parts; quotient (Q) and remainder (R). Sugiura et al. [25] have presented a lossless optimal extension of the GR code to attain great compression performance. This scheme consumes more memory in the encoding part by referring to the GR code table. Several new schemes of modified Huffman encoding [26, 27] have presented in compression to improve the CR and its performance by a minor modification on Huffman.

To minimize the number of required bits and reconstruct the quality of a processed image, encoding and decoding play an important role. After analysis of these different types of encoding schemes, Huffman and GR coder consume less computation time than compared to arithmetic coder even they referred a table to generate bit codes. Modified Huffman encoding increases its computation time by applying the new idea to the existing technique. In the implementation view, the arithmetic coder takes much computation time and higher CR than compared to all other encoders. High compression ratio, easy and fast implementation, good quality of the decoded image without referring any table are the most challenging tasks for researchers. To address these, a new scheme of encoding technique is presented. The key objective of this proposed scheme attains a

71	8	1	0	0	0	0	0
-4	2	1	0	0	0	0	0
-1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

FIGURE 3   Sample QTC block values with qf 20

FIGURE 4   (a) Test image, boat (256 × 256). (b) Huffman at 97.92 CR% and PSNR 23.97 dB. (c) GR at 85.96 CR% and PSNR 22.27 dB. (d) LLEC at 96.74 CR% and PSNR 23.97 dB. (e) Modified Huffman at 97.93 CR% and PSNR 23.97 dB. (f) OPT Huffman at 97.68 CR% and PSNR 25.13 dB. (g) Optimal GR at 97.90 CR% and PSNR 23.97 dB. (h) Proposed coder at 96.91 CR% and PSNR 23.97 dB
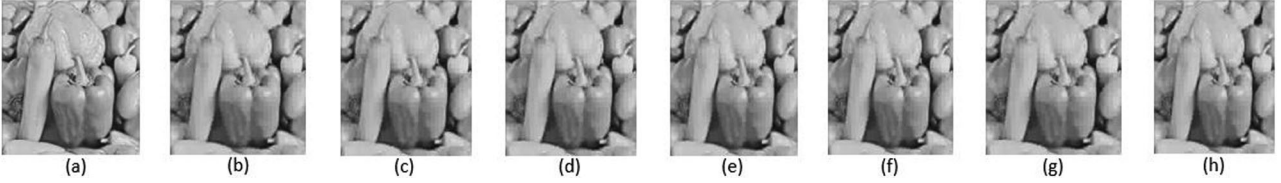

FIGURE 5   (a) Test image, pepper (256 × 256). (b) Huffman at 98.15 CR% and PSNR 27.90 dB. (c) GR at 91.68 CR% and PSNR 27.61 dB. (d) LLEC at 97.23 CR% and PSNR 27.90 dB. (e) Modified Huffman at 98.16 CR% and PSNR 27.90 dB. (f) OPT Huffman at 97.85 CR% and PSNR 28.46 dB. (g) Optimal GR at 95.95 CR% and PSNR 27.90 dB. (h) Proposed coder at 97.68 CR% and PSNR 27.62 dB

high compression ratio and good eminence of a decoded image with low computation time in terms of CR, mean square error (MSE), and PSNR. By applying the encoding techniques, only the minimum number of bits is assigned to quantized transform coefficients and it is lossless in the reverse process to reconstruct the original values.

The rest of this paper is ordered as follows. Detailed descriptions of the proposed scheme are given in Section 2 and Section 3 presents performance measure. In Section 4, the experimental results and comparative analysis are reported and discussed. Section 5 concludes the paper.

2 | PROPOSED SCHEME: FAST AND EFFICIENT LOSSLESS ENCODER WITH LOW COMPUTATION AND LOW MEMORY

In this section, a fast and efficient lossless encoder with minimum computation and low memory is reported briefly. Initially, the original image with the size of $(N \times N)$ is split into $(n \times n)$ blocks where $n < N$, then applied into DCT to reduce the correlation between the pixels, as shown in Equation (1).

$$I^1_{(i,j)} = I_{(i,j)} + DCT \tag{1}$$

FIGURE 6   (a) Test image, lena (256 × 256). (b) Huffman at 98.02 CR% and PSNR 26.73 dB. (c) GR at 90.97 CR% and PSNR 25.89 dB. (d) LLEC at 97.27 CR% and PSNR 26.78 dB. (e) Modified Huffman at 98.05 CR% and PSNR 26.73 dB. (f) OPT Huffman at 98.15 CR% and PSNR 27.86 dB. (g) Optimal GR at 96.65 CR% and PSNR 26.73 dB. (h) Proposed coder at 97.66 CR% and PSNR 26.78 dB
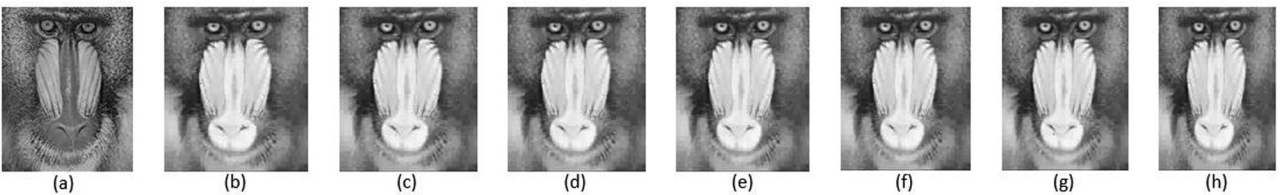
FIGURE 7   (a) Test image, baboon (256 × 256). (b) Huffman at 97.85 CR% and PSNR 22.92 dB. (c) GR at 82.01 CR% and PSNR 22.92 dB. (d) LLEC at 96.34 CR% and PSNR 22.92 dB. (e) Modified Huffman at 97.88 CR% and PSNR 22.92 dB. (f) OPT Huffman at 97.85 CR% and PSNR 25.13 dB. (g) Optimal GR at 97.42 CR% and PSNR 22.92 dB. (h) Proposed coder at 96.32 CR% and PSNR 22.92 dB

FIGURE 8 (a) Test image, barbara (256 × 256). (b) Huffman at 98.15 CR% and PSNR 25.64 dB. (c) GR at 90.75 CR% and PSNR 24.16 dB. (d) LLEC at 97.61 CR% and PSNR 25.64 dB. (e) Modified Huffman at 98.15 CR% and PSNR 25.64 dB. (f) OPT Huffman at 98.15 CR% and PSNR 26.51 dB. (g) Optimal GR at 97.54 CR% and PSNR 25.64 dB. (h) Proposed coder at 97.73 CR% and PSNR 25.64 dB
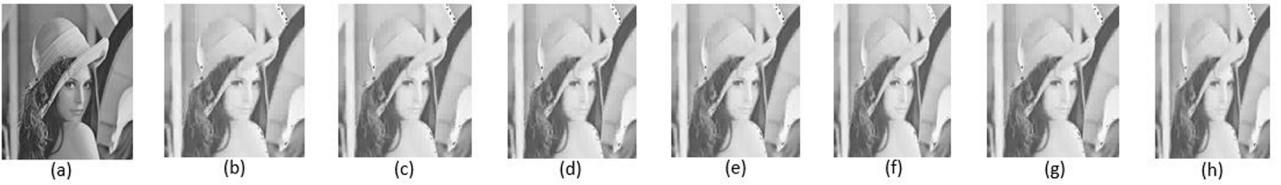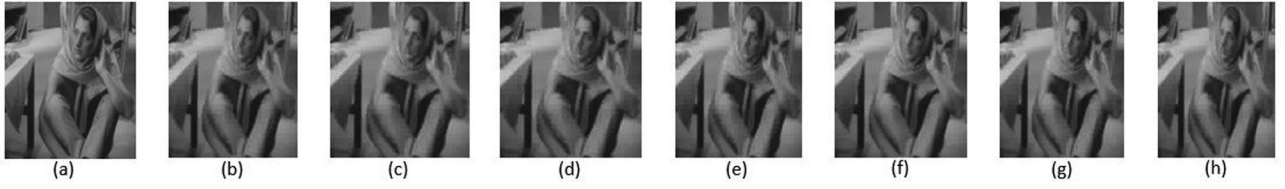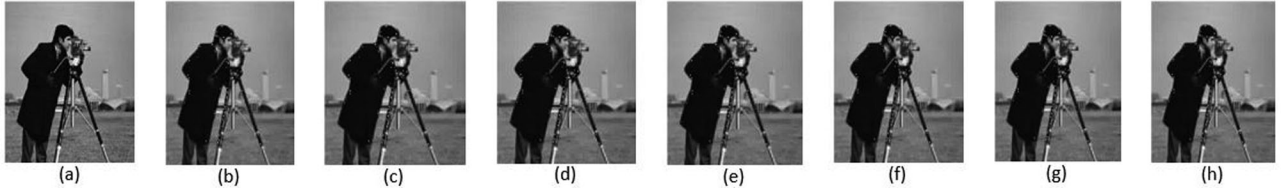

FIGURE 9 (a) Test image, cameraMan (256 × 256). (b) Huffman at 98.09 CR% and PSNR 26.78 dB. (c) GR at 90.63 CR% and PSNR 26.78 dB. (d) LLEC at 97.30 CR% and PSNR 26.78 dB. (e) Modified Huffman at 98.09 CR% and PSNR 26.78 dB. (f) OPT Huffman at 97.85 CR% and PSNR 28.78 dB. (g) Optimal GR at 97.10 CR% and PSNR 26.78 dB. (h) Proposed coder at 97.72 CR% and PSNR 26.78 dB

where $I_{(i,j)}$ and $I'_{(i,j)}$ are the original image and its corresponding DCT image respectively. To achieve high CR, each block of $I'_{(i,j)}$ is subjected to SQ by using quantization matrix, as in JPEG is given below;

$$Q_{(i,j)} = round * \frac{DCT_{(i,j)}}{Quantum_{(i,j)}} \qquad (2)$$

where Q(i,j) is quantized value for the corresponding coefficient DCT(i,j). The qunatum (i,j) values are generated by using the formula, is given below;

$$Quantum_{(i,j)} = 1 + ((1 + i + j) * qf) \qquad (3)$$

where qf is a quality factor which is user input, generally in the range of 0–25. $Q_{(i,j)}$ is assigned with the minimum number of bits by reducing the precision or quantity of $I'(i,j)$. After applying transformation and quantization, Quantized transform coefficients (QTC) are arranged as one-dimensional array elements using zigzag order to eliminate the continuous zero coefficients of the lower right corner of (8 × 8) block in a 2D block. By eliminating these zeroes, it attains a higher CR by storing up to the last non-zero quantized transform coefficient. Finally, the

proposed coder is applied to every block of QTC (8 × 8) and converts the coefficients into bitstream. The proposed coder performs well not only on the blocking sequence of DCT but also on DWT. The proposed scheme in encoding process is shown in Figure 1.

In the reverse process, the lossless proposed coder reconstructs the original bits to denote the decoded image as shown in Figure 2. It attains a great compression with good quality, which is measured by CR and PSNR.

In this proposed work, the code words are uniquely defined by input value and hence, do not need codebook. So, it takes less computation to compress the image when compared to other coders like Huffman, arithmetic, LLEC, and GR coder. To implement a lossless proposed coder to attain high compression, some of the parameters are calculated on the QTC block by (8 × 8). The quantization block is represented as QB. A last non-zero coefficient in QB is represented as P which is considered as the final value. One QB consists of 1 DC and 63 AC coefficients. To assign the minimum bits to DC, DPCM is applied on every QB, as shown in Equation (4)

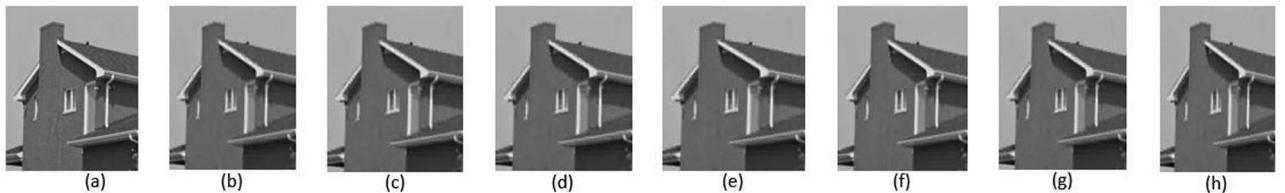$$DPCM = DC_{prev} - DC_{curr} \qquad (4)$$

FIGURE 10 (a) Test image, house (256 × 256). (b) Huffman at 98.21 CR% and PSNR 29.01 dB. (c) GR at 94.10 CR% and PSNR 29.01 dB. (d) LLEC at 98.10 CR% and PSNR 29.11 dB. (e) Modified Huffman at 98.24 CR% and PSNR 29.01 dB. (f) OPT Huffman at 98.20 CR% and PSNR 29.25 dB. (g) Optimal GR at 97.23 CR% and PSNR 29.01 dB. (h) Proposed coder at 98.65 CR% and PSNR 29.24 dB

TABLE 1 CR% values obtained by DCT based proposed coder and other coders for different images with quality factor 5–20

qf	Input images	Huffman	GR	LLEC	Modified Huffman	OPT Huffman	Optimal GR	Proposed coder
5	Boat	94.45	56.51	89.26	94.47	91.97	90.00	83.67
	Pepper	95.52	74.92	92.03	95.53	93.87	90.54	89.74
	Lena	95.39	74.03	91.91	95.40	92.60	92.14	89.34
	Baboon	93.51	42.52	89.33	93.81	90.70	90.24	83.18
	Barbara	96.23	56.74	91.89	96.30	93.59	93.42	84.16
	CameraMan	95.66	72.67	92.21	95.72	92.83	93.18	89.59
	House	96.59	81.24	94.84	95.64	93.79	94.30	93.29
10	Boat	96.06	58.38	91.43	96.10	92.35	92.48	88.86
	Pepper	96.55	76.80	92.87	96.60	94.05	93.37	93.41
	Lena	96.61	75.91	93.63	96.67	94.38	92.48	92.34
	Baboon	95.48	44.39	90.79	95.64	91.16	91.82	85.10
	Barbara	96.82	58.62	94.09	96.90	94.33	94.08	89.57
	CameraMan	96.77	74.54	93.95	96.79	94.72	93.99	93.35
	House	97.28	83.11	95.36	97.31	96.42	95.72	96.48
15	Boat	97.44	71.07	92.98	97.47	96.47	95.98	94.69
	Pepper	97.50	85.18	94.40	97.50	96.97	94.57	96.39
	Lena	97.63	82.33	95.18	97.63	97.06	95.77	96.31
	Baboon	97.22	59.96	92.35	97.31	96.11	94.32	93.30
	Barbara	97.79	72.71	95.59	97.81	97.55	94.73	96.11
	CameraMan	97.70	83.75	95.44	97.69	97.24	95.52	96.35
	House	97.88	89.46	96.93	97.89	98.07	96.21	97.83
20	Boat	97.92	85.96	96.74	97.93	97.68	97.90	96.91
	Pepper	98.15	91.68	97.23	98.16	97.85	95.95	97.68
	Lena	98.02	90.97	97.27	98.05	98.15	96.65	97.66
	Baboon	97.85	82.01	96.34	97.88	97.85	97.42	96.32
	Barbara	98.15	90.75	97.61	98.15	98.15	97.54	97.73
	CameraMan	98.09	90.63	97.30	98.09	97.85	97.10	97.72
	House	98.21	94.10	98.10	98.24	98.20	97.23	98.65

where DCcurr is DC value in the current QB, and DCprev is the DC value in the previous QB.

Finally, it is applied to the proposed coder to generate the bitstream. Every transform coefficient 'n' that is converted into the binary bitstream is marked as b. To split even or odd series of b, the length of b is computed and is represented as L. If L is even a series of the length of b, then the lower number of bits in even series 'p' is computed from the formula.

$$p = \frac{n}{2} \qquad (5)$$

where 'p' number of '0' bit is added in the encoding part followed by '1' bit as the coding is to shorten the correlation between the pixels in which less amount reference bits. Finally, the binary bit of n is added after the reference bits.

```
Algorithm: Proposed coder Input: An
input monochrome image f(x, y) of size
(256 × 256) Output: Encoded bitstreams
using the proposed Coder for each n in
QB up to P do:
i→0
j→0
b→convert binary bitstream of n
L→length of bitstream of b if (L%2 = =
0):
p→n/2 while (i<p):
add '0' bit
i = i+1
add '1' bit after m number of '0' bit
add b bitstream at end of reference bit
else:
q→((n-1)/2)+1 while (j<q):
```

TABLE 2 BPP values obtained by DCT based proposed coder and other coders for different images with quality factor 5–20

qf	Input images (256 × 256)	Huffman	GR	LLEC	Modified Huffman	OPT Huffman	Optimal GR	Proposed coder
5	Boat	0.44	3.48	0.86	0.44	0.64	0.80	1.31
	Pepper	0.36	2.01	0.64	0.36	0.49	0.76	0.82
	Lena	0.37	2.08	0.65	0.37	0.59	0.63	0.85
	Baboon	0.52	4.60	0.85	0.50	0.74	0.78	1.21
	Barbara	0.30	3.46	0.65	0.30	0.51	0.53	1.27
	CameraMan	0.35	2.19	0.62	0.34	0.57	0.55	0.83
	House	0.27	1.50	0.41	0.35	0.50	0.46	0.54
10	Boat	0.32	3.33	0.69	0.31	0.61	0.60	0.89
	Pepper	0.28	1.86	0.57	0.27	0.48	0.53	0.53
	Lena	0.27	1.93	0.51	0.27	0.45	0.60	0.61
	Baboon	0.36	4.45	0.74	0.35	0.71	0.65	1.19
	Barbara	0.25	3.31	0.47	0.25	0.45	0.47	0.83
	CameraMan	0.26	2.04	0.48	0.26	0.42	0.48	0.53
	House	0.22	1.35	0.37	0.22	0.29	0.34	0.28
15	Boat	0.21	2.32	0.56	0.20	0.28	0.32	0.42
	Pepper	0.20	1.19	0.45	0.20	0.24	0.43	0.29
	Lena	0.19	1.41	0.39	0.19	0.24	0.34	0.29
	Baboon	0.22	3.20	0.61	0.22	0.31	0.45	0.54
	Barbara	0.18	2.18	0.35	0.18	0.20	0.42	0.31
	CameraMan	0.18	1.30	0.37	0.18	0.22	0.36	0.29
	House	0.17	0.84	0.25	0.17	0.15	0.30	0.17
20	Boat	0.17	1.12	0.26	0.17	0.19	0.17	0.25
	Pepper	0.15	0.67	0.22	0.15	0.17	0.32	0.19
	Lena	0.16	0.72	0.22	0.16	0.16	0.27	0.19
	Baboon	0.17	1.44	0.29	0.17	0.17	0.21	0.30
	Barbara	0.15	0.74	0.19	0.15	0.15	0.21	0.18
	CameraMan	0.15	0.75	0.22	0.15	0.17	0.23	0.18
	House	0.14	0.47	0.15	0.14	0.14	0.22	0.11

```
add '1' bit
j = j+1
add '0' bit after m number of '1' bit
add b bitstream at end of reference bit
end
```

If L is an odd series of the length of b, then the lower number of bits in even series 'q' is computed from the formula as

$$q = \frac{n-1}{2} + 1 \qquad (6)$$

where 'q' Number of '1' bit is added in the encoding part followed by '0' bit as reference bits. Finally, the binary bit of n is added after the reference bits. Let us consider n is 17. 'b' of n is 10001 and L of b is 5. L is applied to the odd series equation to compute q value that is 3. So that, the reference bit of n is 1110 followed by 10001 as b of n. Finally, the bitstream of 17 using the proposed coder is 100011110. In case the n is a negative coef-

ficient as −12, 'b' of n is 0011(1's complement of 1100), and L of b is 4. L is applied to the even series equation to compute q value that is 2. So that, the reference bit of n is 001 followed by 0011 as b of n. Finally, the bitstream of −12 using the proposed coder is 0010011.

To show the performance of proposed coder, a sample one dimension QTC block after zigzag order with size of (8 × 8) is considered as 71 8 −4 −1 2 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0, and same is shown in Figure 3. The last non zero value in the sequence order is 8, as considered as P. The resulting values of the proposed coder on QTC block are 100011110100011100110001100111000110101100101. The total bit of proposed coder is 45 bits. After applying the Huffman coder, the output values are 111100010001111011100010010000000110 0011100100. The total bit of Huffman coder is 45 bits. When GR coder is applied to the same QTC block, the resultant values are

TABLE 3 PSNR values obtained by DCT based proposed coder and other coders for different images with quality factor 5–20

qf	Input images (256 × 256)	Huffman	GR	LLEC	Modified Huffman	OPT Huffman	Optimal GR	Proposed coder
5	Boat	30.39	30.39	30.39	30.39	31.12	30.39	30.39
	Pepper	36.65	36.65	36.65	36.65	35.62	36.65	36.65
	Lena	36.03	36.03	34.57	36.03	34.12	36.03	36.03
	Baboon	36.03	36.03	29.70	36.03	30.22	36.03	36.03
	Barbara	30.21	30.21	31.09	30.21	31.26	30.21	30.21
	CameraMan	31.76	31.76	36.76	31.76	33.15	31.76	33.76
	House	35.30	35.30	35.30	35.30	35.69	35.30	35.30
10	Boat	28.25	28.25	28.25	28.25	30.12	28.25	28.25
	Pepper	33.38	33.38	33.38	33.38	34.79	33.38	33.38
	Lena	31.64	31.64	31.64	31.64	33.48	31.64	32.08
	Baboon	27.32	27.32	27.32	27.32	29.41	27.32	27.32
	Barbara	28.94	28.94	28.94	28.94	29.13	28.94	28.94
	CameraMan	32.47	32.47	32.47	32.47	32.86	32.47	32.47
	House	33.56	33.56	33.56	33.56	34.71	33.56	33.51
15	Boat	25.86	24.15	24.21	25.86	27.85	25.86	25.86
	Pepper	30.59	29.42	29.12	30.59	31.45	30.59	30.59
	Lena	29.01	28.37	29.84	29.01	31.18	29.01	29.01
	Baboon	24.68	23.48	23.12	24.68	26.47	24.68	24.68
	Barbara	26.86	25.41	27.15	26.86	27.90	26.86	26.86
	CameraMan	29.57	28.82	29.56	29.57	30.12	29.57	29.57
	House	31.37	30.21	31.27	31.37	31.45	31.37	31.37
20	Boat	23.97	22.27	23.97	23.97	25.13	23.97	23.97
	Pepper	27.90	27.61	27.90	27.90	28.46	27.90	27.62
	Lena	26.73	25.89	26.78	26.73	27.86	26.73	26.78
	Baboon	22.92	22.92	22.92	22.92	25.13	22.92	22.92
	Barbara	25.64	24.16	25.64	25.64	26.51	25.64	25.64
	CameraMan	26.78	26.78	26.78	26.78	28.78	26.78	26.78
	house	29.01	29.01	29.11	29.01	29.25	29.01	29.24

TABLE 4 CR% values obtained by DWT based proposed coder and other coders for different images with quality factor 20

qf	Input images (256 × 256)	Huffman	GR	LLEC	Optimal GR	Proposed coder
20	Boat	98.23	94.24	98.29	98.12	97.97
	Pepper	98.15	95.99	98.42	98.18	98.58
	Lena	98.27	95.95	98.42	98.01	98.25
	Baboon	98.15	93.73	98.27	98.16	97.72
	Barbara	98.37	96.27	98.62	98.21	98.49
	CameraMan	98.32	95.67	98.40	98.24	98.43
	House	98.35	95.05	98.79	98.31	98.37

TABLE 5 BPP values obtained by DWT based proposed coder and other coders for different images with quality factor 20

qf	Input images (256 × 256)	Huffman	GR	LLEC	Optimal GR	Proposed coder
20	Boat	0.14	0.46	0.14	0.15	0.16
	Pepper	0.15	0.32	0.13	0.15	0.11
	Lena	0.14	0.32	0.13	0.16	0.14
	Baboon	0.15	0.50	0.14	0.15	0.18
	Barbara	0.13	0.30	0.11	0.13	0.12
	CameraMan	0.14	0.35	0.13	0.14	0.13
	House	0.13	0.37	0.10	0.14	0.13

111101001111000100111001000001001000010000000010000. The total bit of GR coder is 51. The resultant values of LLEC are 0000000110001110000110001001100000101110 01100110. The total bit of LLEC coder is 47. Based on these analyses, the proposed coder assigns the minimum number of bits for lower frequency than compared to other coders. It achieves higher CR, when the qf is increased because of higher levels of length '*n*' low frequencies are obtained at the table.

TABLE 6 PSNR values obtained by DWT based proposed coder and other coders for different images with quality factor 20

qf	Input images (256 × 256)	Huffman	GR	LLEC	Optimal GR	Proposed coder
20	Boat	25.86	24.64	25.86	24.64	25.86
	Pepper	30.59	27.9	30.59	27.9	30.59
	Lena	29.16	27.16	29.16	27.16	29.16
	Baboon	24.68	23.55	24.68	23.55	24.68
	Barbara	26.86	26.12	26.86	26.12	26.86
	CameraMan	29.57	27.85	29.57	27.85	29.57
	House	31.37	30.05	31.37	30.05	31.37

2.1 | Encoding algorithm using proposed coder

The steps involved in the encoding algorithm using the proposed coder are presented in detail below;

```
Input: A monochrome image with the size
of (ROW x COL)
Output: Encoded bitstream using the
proposed scheme
Begin
Step 1: Divide the input image into
(8 × 8) non-overlapping subblocks
```

```
Step 2: Apply DCT to each block of
I(i,j) Step 3: Perform quantization
with various qf as mentioned in Sec-
tion  2 Step 4: After quantization,
arrange coefficients in a zigzag order
scan and find the last non-zero coeffi-
cient value
Step 5: Apply difference pulse code mod-
ulation for DC coefficient of each block
Step 6: Apply the proposed coder for
converting the coefficients into bit-
stream as mentioned in Section  2 End
```

The proposed coder performs well on DCT and DWT and achieves lossless high compression. In the decoding part, the lossless decoded image is extracted by applying the reverse technique of the proposed coder. More than 200 sample images with a size of (256 × 256) are tested using the proposed scheme and compared to other encoding techniques. The obtained results are analyzed with other encoder schemes in Section 4.

2.2 | Decoding algorithm using proposed coder

The steps involved in the decoding algorithm using the reverse process of the proposed coder are presented in detail below;

```
Input: Bitstream of the encoded image
```
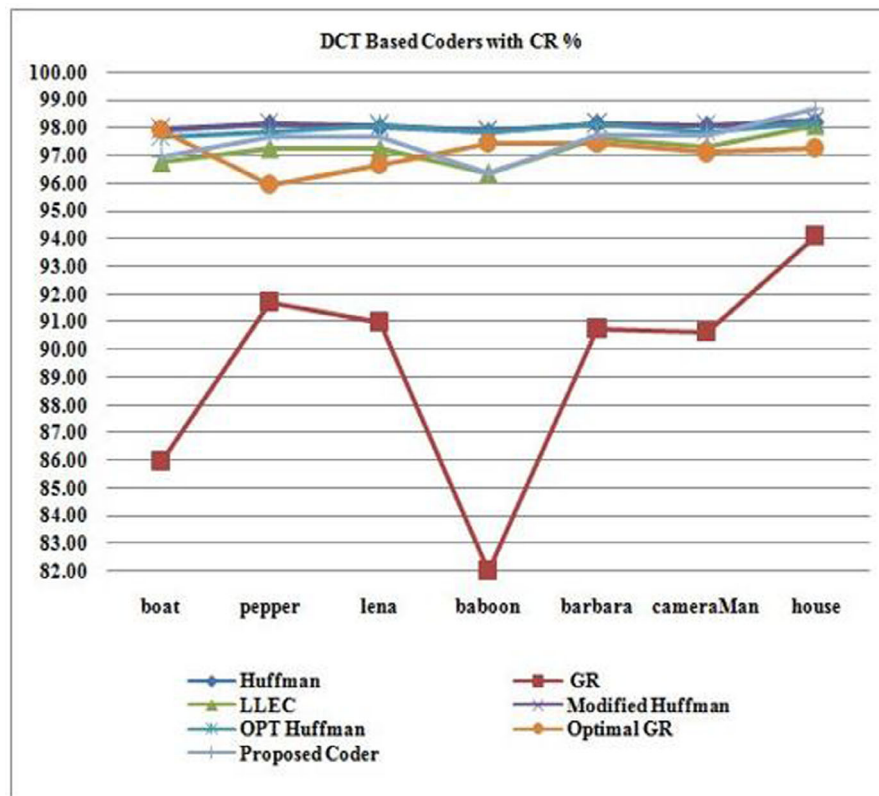

FIGURE 11 Comparison of DCT based encoders CR% for different images with the proposed scheme
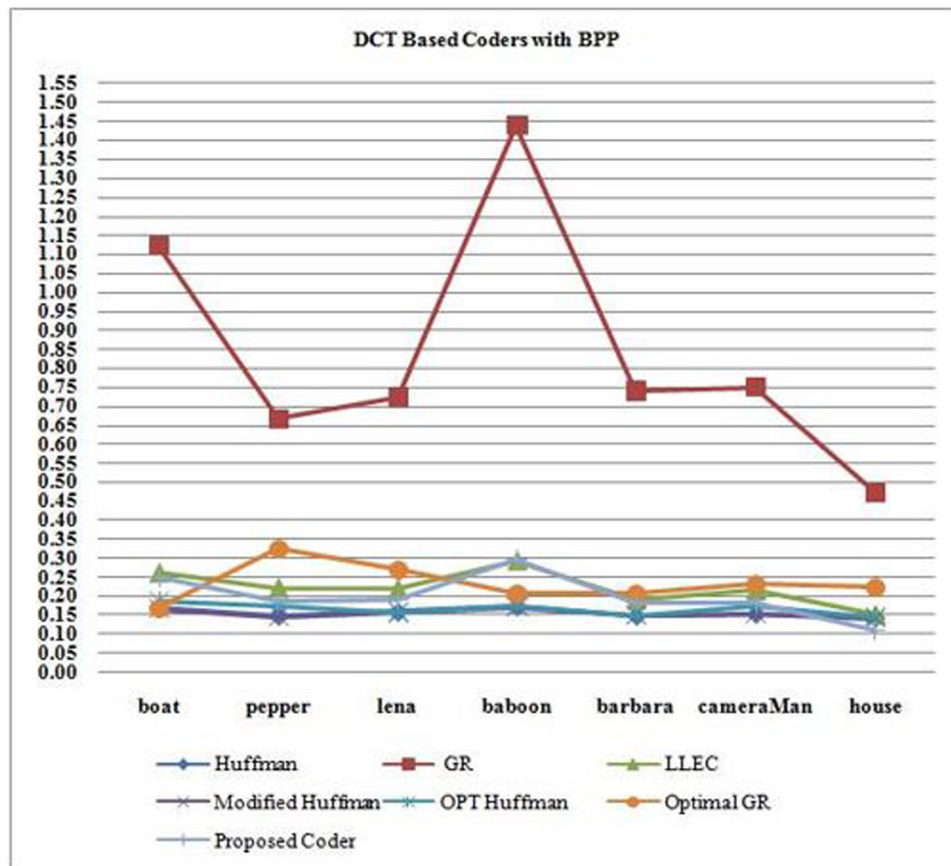
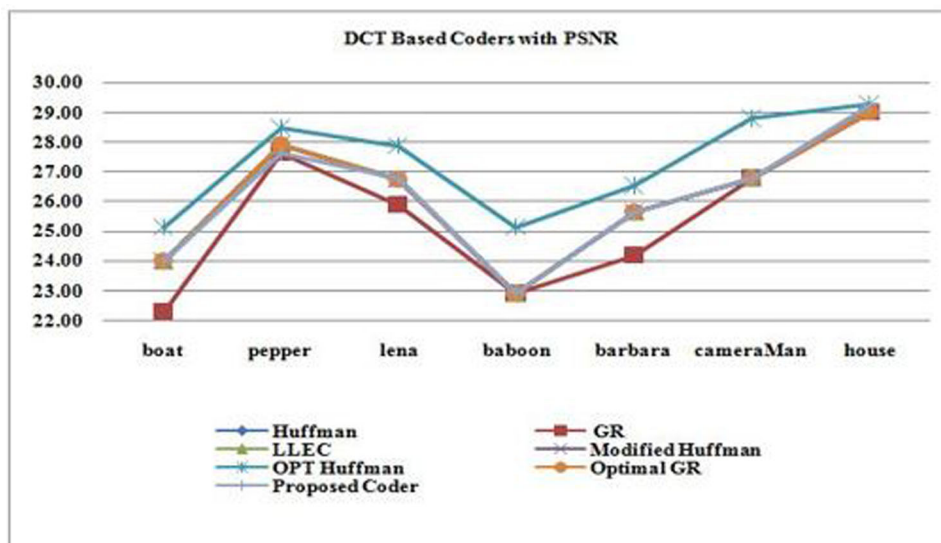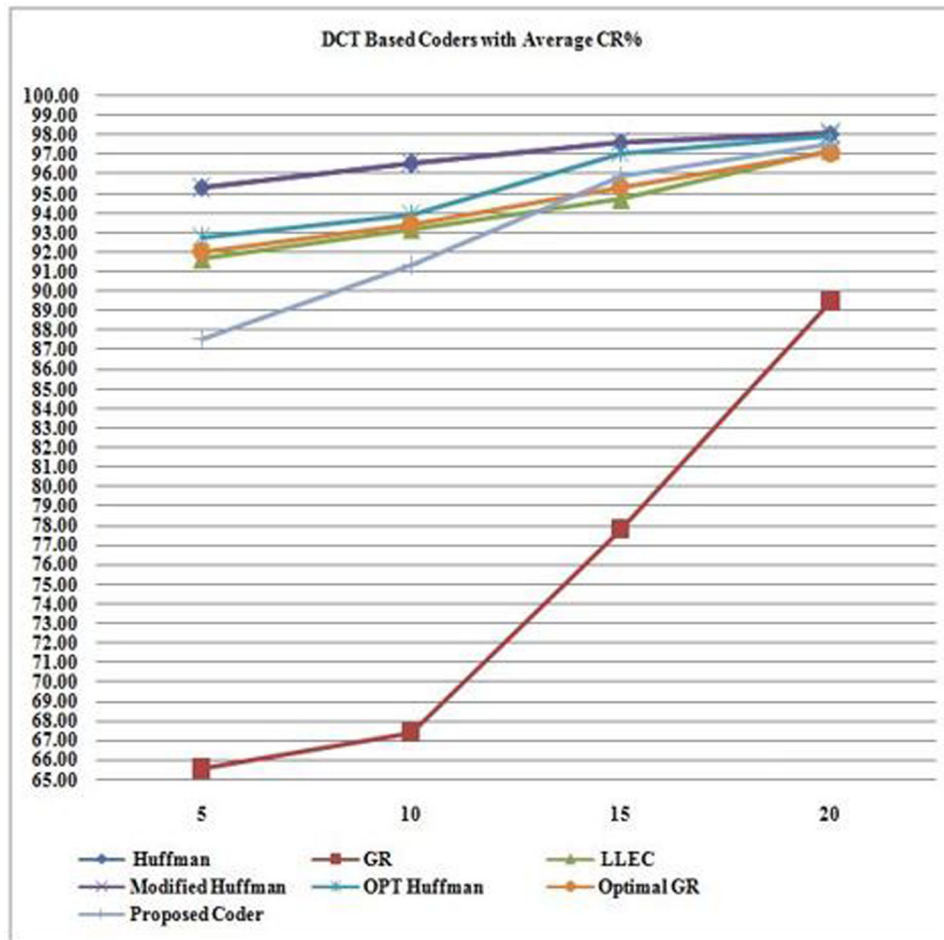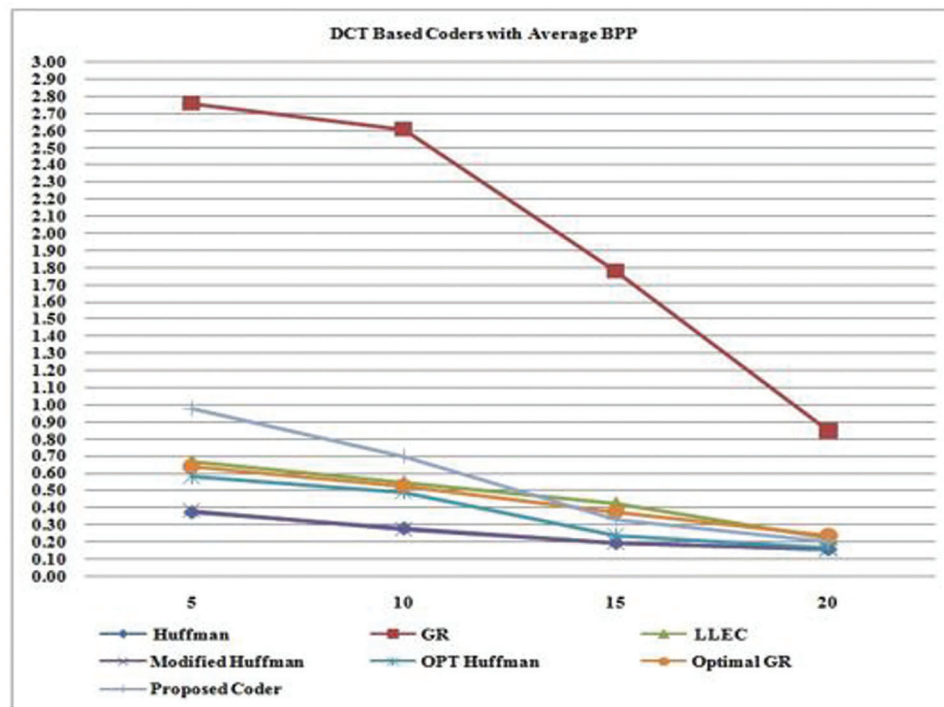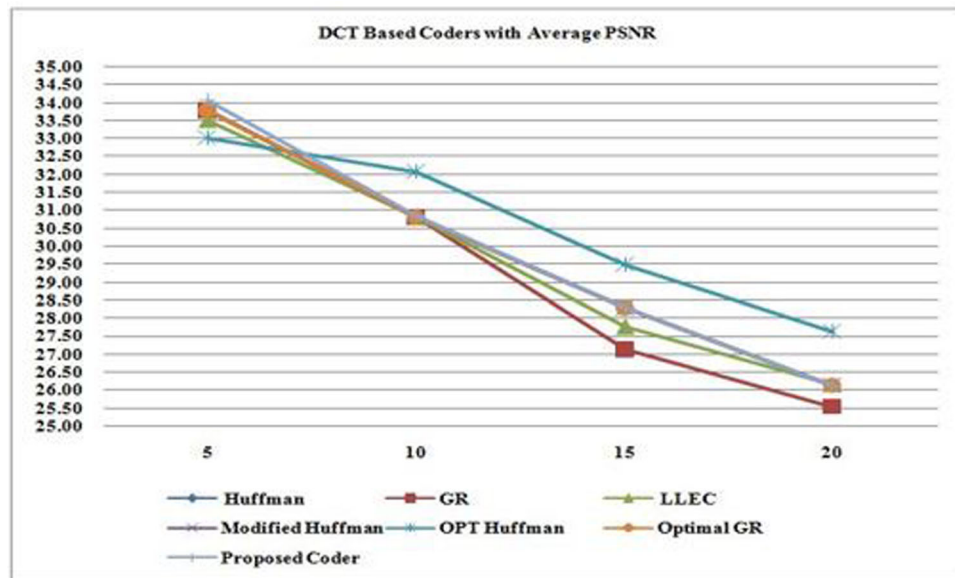**FIGURE 12** Comparison of DCT based encoders BPP for different images with the proposed scheme

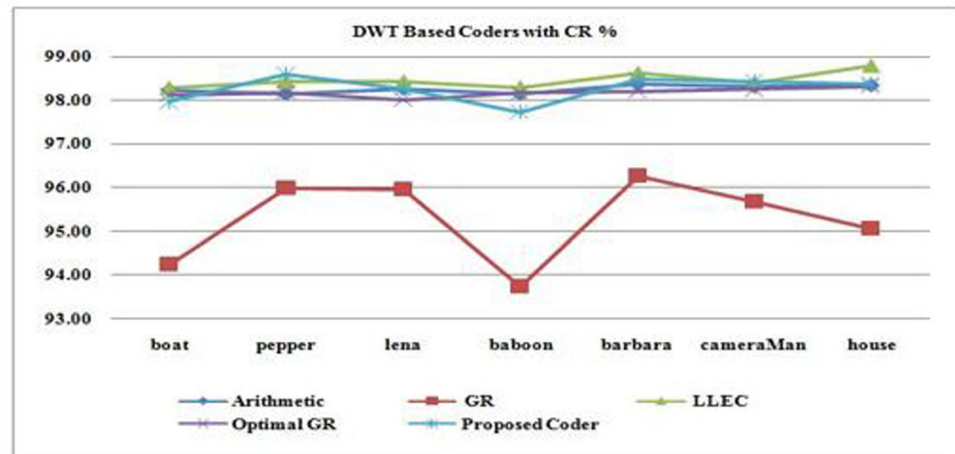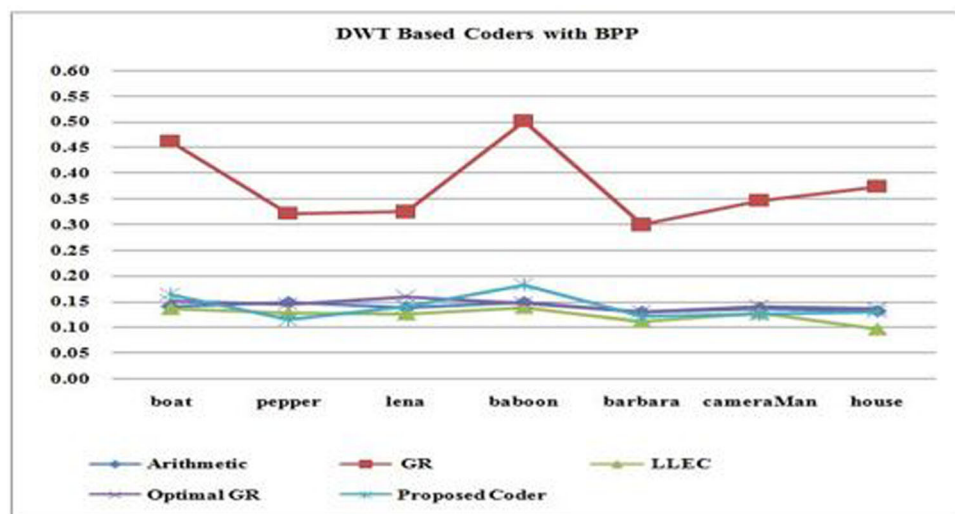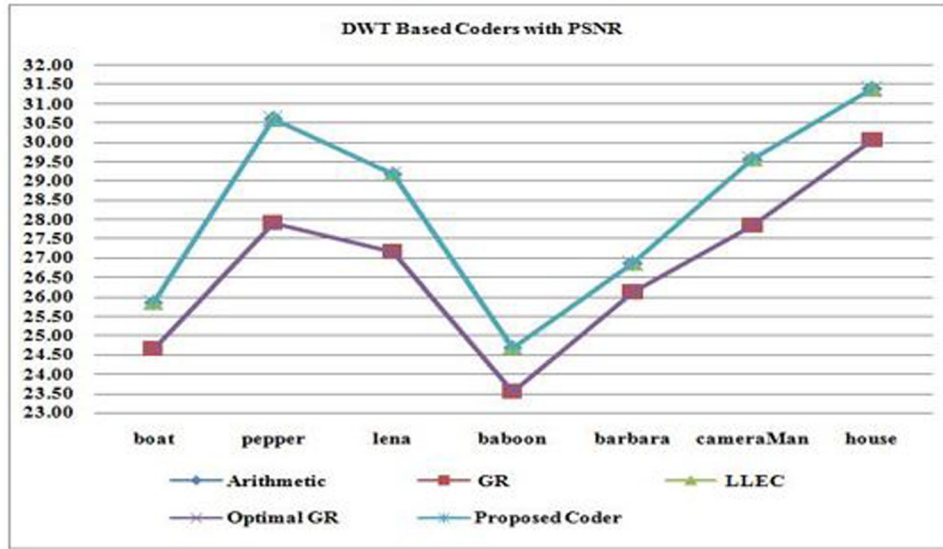**FIGURE 13** Comparison of DCT based encoders PSNR for different images with the proposed scheme

```
Output: Decoded image using the        Step 1: Load bitstream of an image
inverse process of the proposed encod-  from disk
ing algorithm                           Step 2: Apply the reverse process of a
Begin                                   proposed coder that converts the bit-
```

FIGURE 14 Comparison of DCT based encoders Average CR% for different images with the proposed scheme

FIGURE 15 Comparison of DCT based encoders Average BPP for different images with the proposed scheme

FIGURE 16   Comparison of DCT based encoders Average PSNR for different images with the proposed scheme

FIGURE 17   Comparison of DWT based encoders CR% for different images with the proposed scheme

FIGURE 18   Comparison of DWT based encoders BPP for different images with the proposed scheme

FIGURE 19 Comparison of DWT based encoders PSNR for different images with the proposed scheme

```
stream into QTC as mentioned in Sec-
tion  2Step 3: Partition the coeffi-
cients into (8 × 8) block to construct
the decoded block of an image
Step 4: Perform the inverse pro-
cess of differential DC for each
block
Step 5: Apply the de-quantization, then
rearranged in inverse zigzag order
Step 6: Apply the inverse transformation
for each
block, then merge the
partition to obtain the reconstructed
image.
End
```

3 | PERFORMANCE MEASURE

The result of the proposed coder is reported in the experimental parts to differentiate with additional standard encoding techniques. To compute the results, some standard performance assessments were exercised. A new scheme has put-forwarded to achieve a higher compression ratio than other encoding techniques which is computed by

$$CR = \frac{DB}{OB} \tag{7}$$

where DB and OB are represented Decoded Bits and the Original Bits, respectively. The lossless proposed scheme retains the fine standard of the decoded image even if it achieves a high CR. The quality of the resultant image is computed by MSE and PSNR. MSE is described as the cumulative squared error in the middle of the original and reconstructed images. MSE is calcu-

lated as,

$$MSE = \frac{\sum_{MN} [X(m, n) - Y(m, n)]^2}{M * N} \tag{8}$$

Here X(m, n) and Y(m, n) are the pixel values at position (m, n) of native image and decoded image respectively. M and N are the numbers of arguments in the input images, respectively. PSNR is interpreted as the standard measurement between the native and the decoded image.

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \tag{9}$$

where R is the peak signal level of a grayscale image which is taken as 255.

4 | EXPERIMENTS AND RESULTS

More than 200 stable images of different types are tested using the proposed scheme and compared with other standard schemes. Seven sample images viz. boat, pepper, Lena, baboon, barbara, cameraMan, and house with a size of (256 × 256) in the scale of 0–255 are shown in Figures 4(a)-10(a). Input images are applied to DCT and DWT then forwarded to quantization with different qf from 5 to 20 as mentioned in Sectioin 2. To achieve lossless compression, all the coefficients are converted into a bitstream using the proposed coder as mentioned in Section 2. The proposed coding achieves a CR of 83.67%, BPP 1.30, PSNR of 30.39 dB for boat image, CR of 89.74%, BPP of 0.82, PSNR 36.65 dB for pepper image, CR of 89.34%, BPP of 0.85, PSNR 36.03 dB for Lena image, CR of 83.18%, BPP of 1.21, PSNR 36.03 dB for baboon image, CR of 84.16%, BPP of 1.27, PSNR 30.21 dB for barbara image, CR of 89.59%, BPP

of 0.83, PSNR 33.76 dB for cameraMan image, CR of 93.29%, BPP of 0.54, PSNR 35.30 dB for house image, when the qf is 5. Comparison results of CR%, BPP, PSNR for different images with qf 5 to 20 are tabulated in Tables 1, 2, and 3 respectively. The proposed scheme is applied with a maximum of 20 qf for input images and their results as CR of 96.91%, BPP 0.25, PSNR of 23.97 dB for boat image, CR of 97.68%, BPP 0.18, PSNR 27.62 dB for pepper image, CR of 97.66%, BPP 0.19, PSNR 26.78 dB for Lena image, CR of 96.32%, BPP 0.30, PSNR 22.92 dB for baboon image, CR of 97.72%, BPP 0.18, PSNR 25.64 dB for barbara image, CR of 97.72%, BPP 0.18, PSNR 26.78 dB for cameraMan image, CR of 98.65%, BPP of 0.11, PSNR 29.24 dB for house image, and results are shown in Figure 4(h)-10(h). To measure the efficiency of the proposed coder technique, JPEG Huffman, GR coder, LLEC coder, modified Huffman, OPT based Huffman and optimal GR coder on DCT, and arithmetic coder, GR coder, LLEC coder, and optimal GR coder on DWT have experimented, and results are tabulated in Tables 1–3, and 4–6 respectively. The experimental results of Huffman, GR coder, LLEC, Modified Huffman, OPT based Hufman, and optimal GR with a qf of 20 are shown in Figures 4(b)-10(b), 4(c)-10(c), 4(d)-10(d), 4(e)-10(e), 4(f)-10(f), and 4(g)-10(g) respectively. Comparison results of CR%, BPP, and PSNR in DCT for different images with qf 20 are shown in Figures 11, 12, and 13 respectively. Average CR%, BPP, and PSNR values of different encoders with the proposed scheme are calculated for different sets of images with qf from 5 to 20, and the results are shown in Figures 14, 15, and 16 respectively. Under the analysis of these results, the proposed coder gives a very good result of CR and the same quality of PSNR to Huffman with low computation time. Hence, the DCT based proposed coder achieves a good CR and better PSNR with very less computation time.

To improve the CR and retain the better PSNR, the proposed coder is applied to DWT. Their results as CR of 97.97%, BPP of 0.16, PSNR of 25.86 for boat image, CR of 98.58%, BPP of 0.11, PSNR 30.59 dB for pepper image, CR of 98.25%, BPP of 0.14, PSNR 29.16 dB for Lena image, CR of 97.72%, BPP of 0.18, PSNR 24.68 dB for baboon image, CR of 98.49%, BPP of 0.12, PSNR 26.86 dB for barbara image, CR of 98.43%, BPP of 0.12, PSNR 29.57 dB for cameraMan image, CR of 98.37%, BPP of 0.13, PSNR 31.37 dB for house image. Comparison results of CR%, BPP, and PSNR in DWT for different images with qf 20 are tabulated in Tables 4, 5 and 6 respectively, and these results are shown in Figures 17, 18, and 19 respectively. GR coder and arithmetic and LLEC coder have experimented with the same standard images in DWT and the acquired outcomes are given in Tables 4–6.

5 | CONCLUSION

This research proposed a novel encoding technique for achieving lossless image compression with low computation and low memory scheme. On the basis of experimental analysis of results, the proposed scheme achieves good result of CR of 96.91%, BPP 0.25, PSNR of 23.97 dB for boat image, CR of 97.68%, BPP of 0.19, PSNR 27.62 dB for pepper image, CR of 97.66%, BPP of 0.19, PSNR 26.78 dB for lena image, CR of 96.32%, BPP of 0.29, PSNR 22.92 dB for baboon image, CR of 97.73%, BPP of 0.18, PSNR 25.64 dB for barbara image, CR of 97.72%, BPP of 0.18, PSNR 26.78 dB for cameraMan image, CR of 98.65%, BPP of 0.11, PSNR 29.24 dB for house image in DCT and CR of 97.97%, BPP of 0.16, PSNR of 25.86 for boat image, CR of 98.58%, BPP of 0.11, PSNR 30.59 dB for pepper image, CR of 98.25%, BPP of 0.14, PSNR 29.16 dB for lena image, CR of 97.72%, BPP of 0.18, PSNR 24.68 dB for baboon image, CR of 98.49%, BPP of 0.12, PSNR 26.86 dB for barbara image, CR of 98.43%, BPP of 0.13, PSNR 29.57 dB for cameraMan image, CR of 98.37%, BPP of 0.13, PSNR 31.37 dB for house image in DWT. The proposed encoder does not refer to any table in the encoding bit conversion part like Huffman and its very fast and simple algorithm with low computation when compared to other standard encoding techniques. It is observed that it gives good quality of decoded images in PSNR equal to Huffman encoding. At an initial stage of quality factors 5 and 10, the proposed scheme does not achieve a better compression ratio while maintaining the same PSNR value as the other coders. At the final stage of qf of 15 and 20, it achieves a very good result of CR, MSE, and PSNR value in DCT and DWT. Still, the predominant challenge in compression is degradation in the quality of decoded image for high compression by applying quantization. In the future, the design of lossless video compression with low computation and low memory will be focused.

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