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Improved Image Compression Scheme Using Hybrid Encoding Algorithm

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Abstract
A color image compression is the most challenging task in the field of multimedia. During last decades several techniques are developed for improving the quality, coding time and compression ratio using different coding strategies. In this work, an effective compression method for hybrid images is proposed based on the discrete wavelet transformation and hybrid encoding algorithm (Huffman and SPIHT). This paper's primary participation is to take advantage of the hybrid encoding technique to maintain the quality of the reconstructed image and the reduction of time complexity. The sample test images are taken from both standard image database and high-quality images (SD and HD). The performance of the proposed scheme is evaluated by using different metrics such as (PSNR, compression ratio and encoding time). Test results indicate that the time and compression ratio of encoding are improved in the expense of the image quality.

Keywords: Hybrid coding, DWT, Adaptive quantization, PSNR, Compression ratio, Encoding time.

1. INTRODUCTION

Image compression is a distinctive picture transmission option because of the limitation of the channel bandwidth and the request for fast transmission. The increasing of spatial and color resolution is required to obtain the high-quality image. For saving these images the problem of the storage limitation is also faced. For the above reasons the image compression plays an important role. An immense amount of information that existed on the on-line websites can be shown in either graphical or pictorial in the nature. Therefore, applying compression algorithm on the data proceeding storage and/or transmission is one of the crucial real-world and considerable concern [1]. Compression method is split into compression of data and multimedia compression [2]. Multimedia has a large storage size that requires plenty of time to upload and download over a network. Multimedia can be represented by different elements such as (image, video, audio, etc.,) files. Image compression can be implemented in both spatial and frequency domain for separating the objects (energy compaction) from the background (noise) [3]. For image compression, frequency transformation shows better compression ratio than the spatial domain. It is possible to classify compression methods either lossless or lossy technique [4]. The lossless compression especially helpful in picture archiving and makes it possible to compress and decompress the picture without loss of any data; the recreated image is identical to the original image. The lossy compression increases the compression ratio with some quality degradation relative to the original image [5].

Lossy compression has a broad variety of uses such as (television transmission, video conferencing, and facsimile transmission, etc.,) in these circumstances specific amount of error is acceptable. Image compression is intended to eliminate the number of bits required to represent an image. Lossless image compression is determined by the low compression ratio while in lossy compression algorithms the coded image acquires a high compression ratio based on human visual properties [6, 7]. In [8] the compression-based transformation has a low computational complexity and capable of accumulating the lowest number of coefficients of signal energy. There is (DFT) discrete Fourier transform, (DWT) discrete wavelet transform, and (DCT) discrete cosine transform based compression method with reversible, linear, corresponding and continues power characteristics. [9]. recently, most research in image encoding has focused on the discrete wavelet transform (DWT). Discrete wavelet transform is basically partitioning the image into four various frequency bands (LL, LH, HL and HH) where the LL sub-band represents the image approximation while the HH sub-band represents the detail and the noise in the image [10]. DWT provides adaptive spatial-frequency resolution that is relevant to the characteristics of human visual system (HVS). It can provide better image quality than DCT, especially when the compression ratio is greater [11]. Set partitioning in hierarchical trees (SPIHT) coding algorithm presented by Said and Pearlman [12] is a very effective technique for image compression based on wavelet transforms. SPIHT is an enhanced and expand version of embedded zero tree wavelet (EZW) encoding algorithm. It affords an embedded bit stream from which the best reconstructed images in the mean square error sense can be take out at various bit rates [13]. The rest of the paper is organized as follows; in section 2, the related works are described. In section 3 the proposed algorithm is presented through different phases. In section 4 and 5 test results of the proposed scheme are evaluated and discussed. Finally, the main conclusions are outlined in section 6.

2. RELATED WORK

L.B Jaffar et al. [14] have performed a comparative analysis of DCT and DWT image compression. An experimental result showed, DWT algorithms do better than DCT algorithm algorithms. The most distinctive feature of using DWT and Inverse DWT, it’s not just going to compress an image efficiently, but will also help maintain the image quality as it was in its original form, which was hardly possible in other image compression techniques earlier.

H.P Jagadish and M.K Lohit [15] have presented DWT and DCT implementation lossy based techniques with the Huffman encoding algorithm. Test results have indicated the high quality of reconstructed image (PSNR) compared to the previous algorithms. Experimental findings showed that a compression ratio of up to 0.8456 is achieved. J. Chunlei and S. Shuxin [16] have proposed a hybrid compression technique that makes use of both fractal concept and SPIHT concept. Experimental results presented that the hybrid image compression algorithm not only increases the coding efficiency and the quality of the reconstructed image but also the encoding time of an image was reduced. B. Sunil and S. Shipra [17] have proposed a hybrid approach to compression which consists of two stages. At first, a high- pass filter, filters the image to get the regions with information. Later, a Huffman-based hybrid system and adaptive interpolation are used to encode the original picture. The obtained compression ratio was enough high, however, PSNR and SSIM are better than other available techniques. Results showed that for the same compression ratio, it provides better quality images than JPEG2000.

L. Wei et al. [18] have presented the SPIHT and Huffman combination coding approach. The experimental results showed that the method has saved a lot of bits in transmission for further enhancing the compression performance. K. Chandrashekhar and S. Monisha [19] have developed compression of images using integrated wavelet- based image coding methods such as EZW, SPIHT and modified SPIHT in combination with Huffman encoder for further compression. Simulation results indicated that the hybrid algorithm bring a better PSNR values at low bit rates. A.M. Aree and A.H Jamal [20] have developed hybrid schemes (DWT and DCT) for image-based compression. They used distinct compression thresholds for the wavelet coefficients of each DWT band (LL and HH) to obtain a greater compression ratio while applying DCT transform on (HL and LH) band. Encoding entropy (variable shift coding) is used to encode the coefficients. Experimental findings showed that the hybrid DWT and DCT can greatly improve the encoding efficiency algorithm. A.N. Ahmed and H. Hussain [21] have proposed a compression technique based on the DWT transformation. In which the redundancy of DWT detail coefficients is reduced by the threshold and by Huffman encoding further reduced. The quality of the compressed images was assessed using certain variables such as CR and PSNR. Experimental findings showed that the proposed method supplied a sufficiently greater compression ratio compared with other thresholds methods.

R. Bhawna et al. [22] have carried out a comparative study of compression algorithm JPEG and SPIHT.With distinct compression ratios, distinct kinds of normal test images are regarded. Some objective picture quality measurements such as PSNR, maximum difference (MD), least mean square error (LMSE), structural similarity index (SSIM) and picture quality scale (PQS) are used to assess image quality. The comparison is based on the outcomes for all above measurements. Compression based on SPIHT obtained better outcomes for all the quality parameters compared to JPEG. J.P.Smitha and P.G. Jayanand [23] have made a comparative analysis of compression methods. Performance test results showed that the run length encoding (RLE) is lossless method and can preserve the image quality but cannot be applied to medical images because it has a very low compression ratio. JPEG coder efficiency performs at average bitrates for a reduced compression ratio DCT-based picture, Due to the artifacts from the block- based DCT system, image quality passes down at greater compression ratios. On the other hand, at low bit rates, wavelet- based coding offers significant improvements in image quality due to overlapping baseline functions and improved wavelet transform energy compaction attribute. SPIHT is the most effective method as regarding of compression ratio and PSNR value. Despite the rise in compression degree, SPIHT maintains the image quality well.

3. METHODS AND MATERIALS

A modern compression system for images based on a hybrid (SPIHT and Huffman) encoding using DWT and adaptive quantization is proposed. The main contribution of the proposed scheme is to improve the compression ratio of the picture while maintaining the quality of the reconstructed image, and reducing encoding time especially for high quality images. This describes the steps of the suggested technique as follows:

- Convert input color image from RGB into YUV color space.
- Apply DWT to the Y component that decompose the gray picture into four distinct sub-bands (LL, HL, LH, HH) while adding the U, V parts in the reconstruction stage.
- Perform adaptive quantization according to the wavelet bands. The approximation band (LL) is quantized with a small quantization step whereas the details sub-bands (HL,LH,HH) are quantized with a larger quantization step.

- Encoding the quantized LL band with the Huffman coding to preserve the reconstructed image quality (i.e., PSNR).
- Encoding the quantized other bands using SPIHT algorithm to reduce encoding time and increase the compression ratio.
- The output of the above steps is a compressed image.
- To reconstruct the original image from the compressed image, each sub-band is applied to decode, de- quantize, IDWT, and reverse color conversion. The algorithm's overall block diagram is shown in Figure **1.**

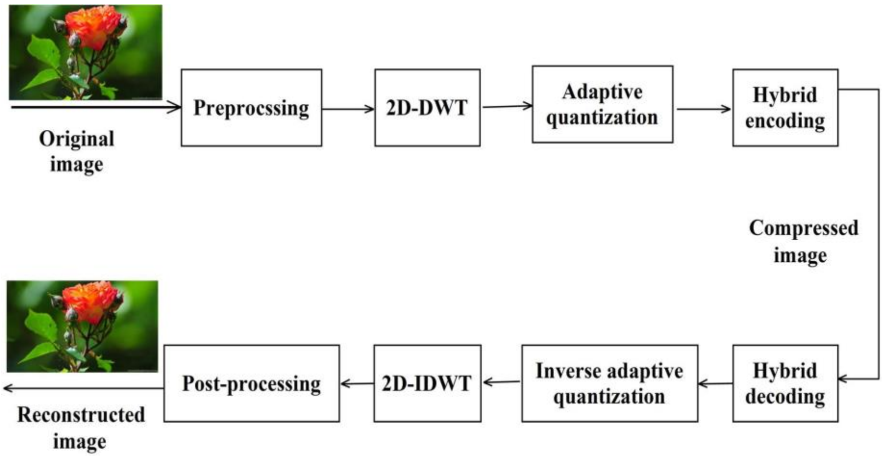

Figure 1: General block diagram of hybrid image compression scheme.

3.1 Compression steps

In this section the necessary steps to compress a color image are described in detail as follows:

3.1.1 Color space conversion (RGB to YUV)

Using the YUV color space can be helpful for image/video compression. It encodes a color image / video that takes into consideration human eye characteristics that allow decreased bandwidth for parts of chrominance without perceptual distortions. Equations shown below are used to perform the color space conversion from RGB to YUV.

$$Y = 0{,}299 * R + 0{,}587 * G + 0{,}114 * B \quad (1)$$

$$U = -0{,}14713 * R - 0{,}28886 * G + 0{,}436 * B \quad (2)$$

$$V = 0{,}615 * R - 0{,}51499 * G - 0{,}10001 * B \quad (3)$$

An example of converting the RGB color space into YUV is demonstrated in Figure 2.

Figure 2: Color space conversion RGB2YUV.

3.1.2 Forward discrete wavelet transforms (FDWT)

On Y-component, the first level DWT is implemented. This creates four separate sub-bands. Low-pass LL band and three high-passes (HL-Vertical, LH-Horizontal and HH-Diagonal) bands. The LL band includes coefficients of approximation, while the rest of the sub-bands have detailed coefficients as shown in Figure 3.

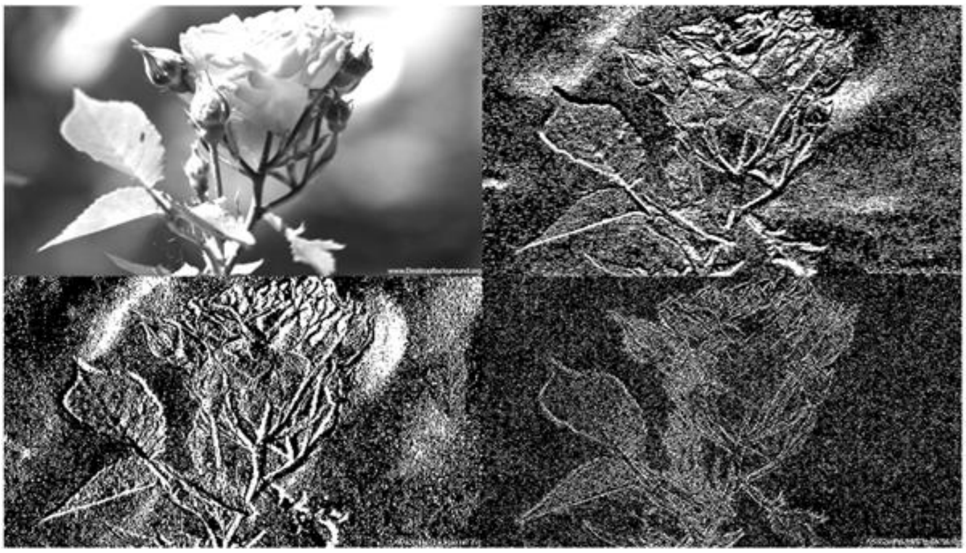

Figure 3: FDWT applied on Y-component.

3.1.3 Adaptive quantization

Adaptive quantization step is applied at the cost of image quality to the sub-band coefficients produced by the FDWT in order to reduce the number of bits needed to represent them. The output is a sequence of integer numbers which have to be encoded bit-by-bit. The quantization steps according to different bands are tuning to control the quality of reconstructed image. For the high compression ratio, the large quantization step is required but this lead to degrade the image quality and the technique will be lossy. With no quantization step the compression is lossless. In order to maintain the image quality, the approximation coefficients (LL) need the smaller step of quantization than the detailed coefficients.

3.1.4 Hybrid encoding technique

Firstly, a Huffman encoding algorithm is applied on the approximation coefficients to take the advantage of compressing the image data in a lossless manner while the image quality is preserved. Secondly, the SPIHT encoding algorithm is performed on the detailed coefficients which can be helpful for reducing the encoding time. Finally, the total encoded bit stream obtained from both the Huffman and SPIHT encoding techniques can be transmitted or stored for further processing. Figure 4 represents the block diagram of the compression steps.

3.2 Decompression stage

This stage is used for reconstructing the original image. It started by applying the hybrid decoding (Huffman and SPIHT) algorithms, followed by the inverse adaptive quantization method to retain the transformed coefficients (approximation and detailed). To convert the transformed coefficients from frequency into spatial domain the first level of inverse discrete wavelet transformation (IDWT) is applied. Finally, the color space conversion for YUV to RGB is performed to get the original image. In Figure 5, the block diagram of the inverse compression steps is shown.

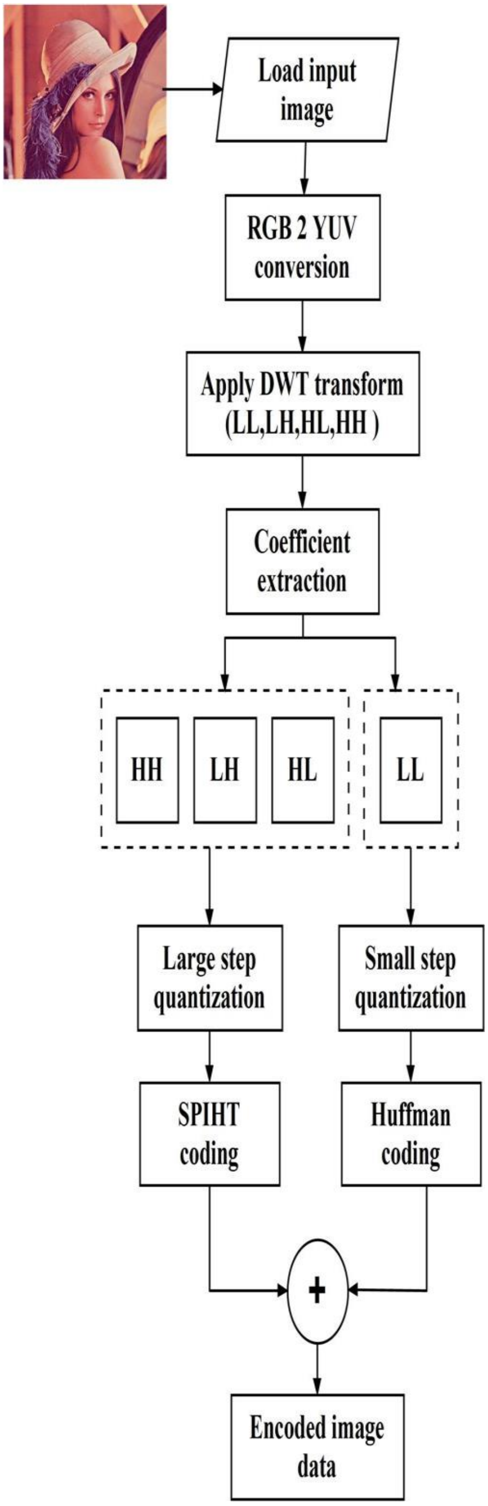

Figure 4: Forward compression block diagram.

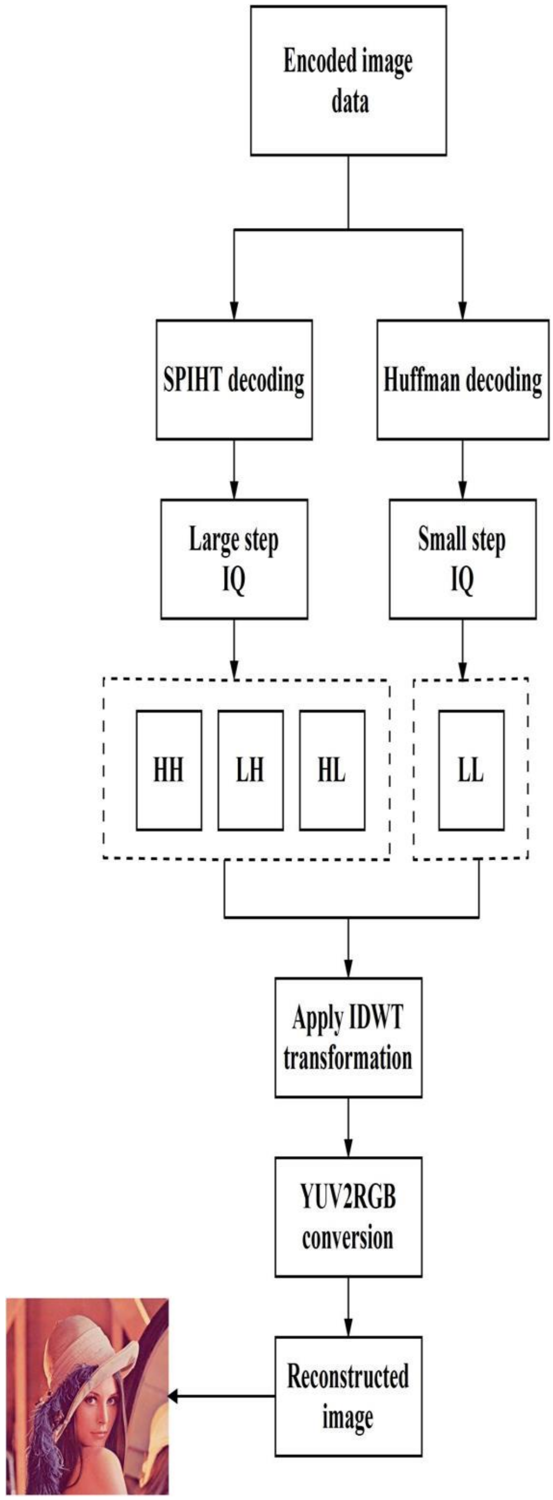

Figure 5: Inverse compression block diagram.

4. RESULTS

In this section, the test sample images and the involved parameters which affect the quality, the compression ratio and computational time are illustrated in the next sub sections.

4.1. Test samples

The implementation of the proposed hybrid compression scheme will be tested on the set of images including SD and HD qualities as shown in Figure 6. Image type, file sizes and the resolutions are illustrated in Table 1:

Table 1: Test sample images

No.	Image	Type	Resolution	Bpp.
1	Lenna.bmp	SD	512 × 512	24
2	Peppers.bmp	SD	512 × 512	24
3	Baboon.bmp	SD	512 × 512	24
4	Rose.bmp	HD	1280 × 720	24
5	Bird.bmp	HD	1280 × 720	24
6	Grape.bmp	HD	1280 × 720	24

Figure 6: Test sample images.

4.2 Quality measure parameters

To evaluate the objective quality between the uncompressed and reconstructed images, PSNR is determined. For calculating the compression gain, compression ratio between uncompressed and compressed image size is used. Finally, the computation time is obtained through encoding and decoding time.

4.2.1 Peak signal to noise ratio

The calculation of PSNR is based on equation 4:

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (4)$$

Where MSE is the mean squared error between the input image X_{ij} and the output image Y_{ij} of the size $M \times N$, which is calculated by the equation 5:

$$MSE = \frac{1}{M \times N} \sum_{i=1}^{m} \sum_{j=1}^{n} \left(x_{ij} - y_{ij}\right)^2 \quad (5)$$

4.2.2 Compression ratio

The following formula is used to determine the CR:

$$CR = \frac{\text{Size of original image}}{\text{Size of compressed image}} \quad (6)$$

4.2.3 Test results without quantization

In this section, the result of PSNR, CR, encoding, and decoding time is presented for both SD and HD images. Table2 shows the simulation results for PSNR and CR without performing quantization while in Table 3 the encoding and decoding processing time are shown. In Table 2 and 3, the first level of wavelet decomposition is applied on the tested images. In Table 4 and 5, the effect of the wavelet band levels for the same performance parameters as mentioned in Table 2 and 3 are presented. The tests are performed using only the proposed hybrid scheme.

Table 2: PSNR and CR for different coding schemes.

Image Name	Huffman		SPIHT		Hybrid	
	PSNR	CR	PSNR	CR	PSNR	CR
Lenna	57.88	2.04	42.26	5.48	44.76	3.03
Peppers	57.15	1.97	42.03	5.44	43.54	2.8
Baboon	57.19	1.58	35.71	5.59	40.24	2.66
Rose	57.69	5.2	28.43	21.18	43.85	8.29
Bird	57.34	4.75	21.19	21.19	42.49	8.35
Grape	57.86	4.42	27.81	21.29	41.00	7.21

Table 3: Encoding and decoding time for different encoding technique.

Image Name	Huffman		SPIHT		Hybrid	
	ET	DT	ET	DT	ET	DT
Lenna	31.19	28.76	7.12	3.94	17.12	13.9
Peppers	32.03	29.69	7.16	3.95	17.81	14.48
Baboon	39.88	36.75	7.73	4.62	19.49	16.28
Rose	44.62	42.14	7.7	3.03	22.26	17.09
Bird	49.92	46.93	8.14	3.04	24.35	19.12
Grape	53.42	50.64	7.45	2.8	26.89	21.18

Table 4: PSNR and CR for different levels of DWT.

Image Name	Level-1 decomposition		Level-2 Decomposition		Level-3 Decomposition	
	PSNR	CR	PSNR	CR	PSNR	CR
Lenna	44.76	3.03	42.5	4.48	42.24	4.73
Peppers	43.54	2.80	42.31	4.42	42.06	4.71
Baboon	40.24	2.66	39.65	3.92	35.8	5.24
Rose	43.85	8.29	38.35	13.18	34.04	16.74
Bird	42.49	8.35	37.13	12.77	36.48	16.01
Grape	41.00	7.21	35.27	12.35	30.87	16.45

Table 5: ET and DT for different levels of DWT.

Image name	Level-1 decomposition		Level-2 Decomposition		Level-3 Decomposition	
	ET	DT	ET	DT	ET	DT
Lenna	17.12	13.9	10.24	6.97	7.46	4.76
Peppers	17.81	14.48	9.67	6.98	7.73	4.99
Baboon	19.99	16.39	13.19	9.69	8.63	5.88
Rose	22.26	17.09	11.12	6.72	7.47	3.25
Bird	24.35	19.12	11.71	7.06	8.17	3.84
Grape	26.89	21.18	12.44	7.87	7.67	3.44

4.2.4 Test results using adaptive quantization

The adaptive quantization steps are applied on the entire bands (LL, LH, HL and HH) for different DWT levels of decomposition. In Table 6, the results of PSNR and CR are given only for SD image whereas in Table 7 the same results are presented for HD image. In both tables, to maintain the quality of the reconstructed image, the quantization step performing on the LL band is equal to one. According to the Table 6, the hybrid method is optimal in terms of PSNR and CR for different wavelet levels. When the quantization step is increased the PSNR is decreased while the CR is increased. However, when the same method is applied on the HD image the relation between PSNR and CR is not optimal for different quantization steps. To overcome this problem, another quantization step is found based on the log2 of the maximum value in each band (Approximation and Details) separately as described by the equation 7. Where Cij represent the DWT coefficients. Table 8 presents the effect of the new quantization step on the PSNR and CR for HD image and compared with one that there is no quantization

$$Q = \log_2 (|\, MAX(C_{ij})\, |) \tag{7}$$

Table 6: Effect of adaptive quantization on PSNR and CR for SD Image.

Q.Steps	Level-1 Decomposition		Level-2 decomposition		Level-3 Decomposition	
	PSNR	CR	PSNR	CR	PSNR	CR
5	41.52	3.69	40.94	5.12	40.66	5.46
10	37.54	4.34	36.46	6.54	36.11	7.13
15	35.98	4.46	34.48	6.85	34.03	7.5

Table 7: Effect of adaptive quantization on PSNR and CR for HD Image.

Q.Steps	Level-1 Decomposition		Level-2 decomposition		Level-3 decomposition	
	PSNR	CR	PSNR	CR	PSNR	CR
5	45.06	8.14	40.77	12.93	36.4	16.52
10	42.12	9.13	40.77	12.93	36.4	16.52
15	40.81	9.23	38.67	13.15	34.36	16.71

Table 8: Hybrid method results with and without quantization for HD image.

Decomposition levels	Without Quantization		With quantization	
	PSNR	CR	PSNR	CR
Level-1	43.85	8.3	42.18	12.7
Level-2	38.35	13.18	38.01	15.86
Level-3	34.04	16.74	36.89	17.52

5. DISCUSSION

Compression techniques such as Huffman, SPIHT and hybrid (Huffman and SPIHT) are applied on a set of standard and HD images. From the outcomes acquired, it is shown that the drawback of using SPIHT for reconstructed HD images is the low value of PSNR while Huffman coding for all images (SD+HD) requires more encoding time. The proposed hybrid coding scheme improves the quality of the images with high PSNR values at lower bitrates compared to the previous methods. The PSNR and CR values of the images with the three techniques are mentioned above in Table 2 and Table 3 for one level of wavelet decomposition. The same tests are performed for different wavelet levels. Results indicate that the PSNR has an optimal value in level one whereas the CR is getting higher value in level three with a significant reduction of encoding time. Another improvement in PSNR, CR and ET is added through the adaptive quantization which is applying on the entire wavelet bands. Results in Table6 and Table7 show that the value of CR is increased for both SD and HD images while preserving the quality of reconstructed image with an acceptable value of PSNR. Finally, the optimal CR value is achieved with the proposed method is 17.52 for the HD image 'Rose. bmp' with the PSNR 36.89 dB.as indicated in Table 8. Figure 7 illustrates the quality values of the original and reconstructed SD and HD images for our proposed schemes using quantization step.

Table 9: PSNR vs. CR between proposed and previous.

Image name	SPIHT		Ref. [24]		Proposed	
	PSNR	CR	PSNR	CR	PSNR	CR
Lenna	38.49	54.93	40.27	84.78	40.67	81.87

From Table 9, the CR of the suggested technique is noted, for the Lenna image is equal to 81.87 that are between 54.93 of the conventional SPIHT and 84.78 in B. Kranthi et al. [24]. This result is acceptable because there is an improvement in the PSNR value. PSNR improvement of 5.66% is achieved compared to the conventional SPIHT.

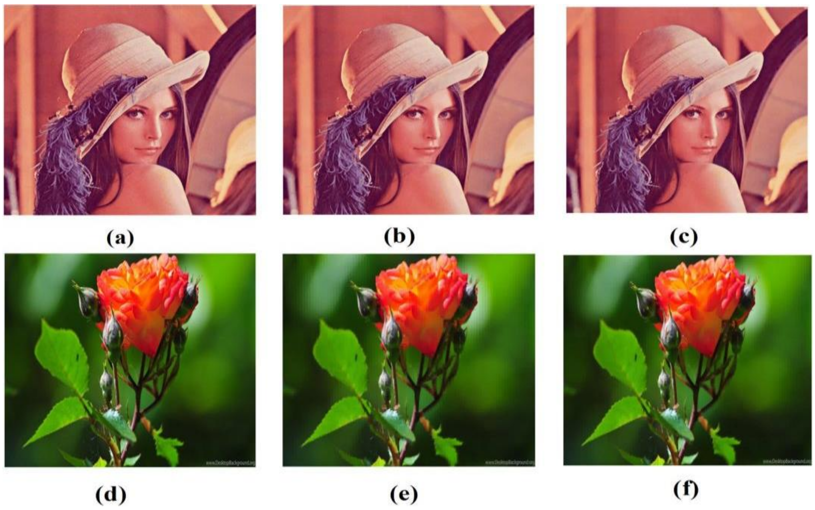

Figure 7:PSNR comparison with and without quantization: (a) Original image Lenna, (b)Reconstructed image with-out Q, PSNR=42.24 dB, (c) Reconstructed image with Q, PSNR=36.34 dB, (d) Original image (Rose),(e) Reconstructed image without Q, PSNR=43.85 dB, (f) Reconstructed image with Q, PSNR=36.89 dB.

6. CONCLUSION

A hybrid (standard and high definition) image compression system based on DWT and hybrid (Huffman + SPIHT) coding algorithm is suggested in this research work. This method is tested on different images using distinct wavelet decomposition levels (first, second and third). To reduce the number of bits needed to represent the transformed wavelet coefficients an adaptive quantization is applied. Conducted results indicate that, the CR value equal to17.52 with (PSNR=36.89dB) for HD image. While for the standard image the CR value equal to 6.54 with (PSNR=36.46dB). The encoding time for the proposed scheme is decreased from 7.46 s to 4.16 seconds for the Lenna image.

7. FUTURE WORKS

The future work will be using more sophisticated techniques to improve the compression ratio for HD images (2k,4k and 8k) while preserving the quality of reconstructed image. Another point will be the benchmarking of the proposed method using the same datasets, working toward the implementation of the proposed hybrid encoding techniques (Huffman + SPIHT) for the H.265 video encoding standard and the encoding of videos with fast object movements.

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