JENRS

Images Compression using Combined Scheme of Transform Coding

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ABSTRACT: Some problems want to be solved in image compression to make the process workable and more efficient. Much work had been done in the field of lossy image compression based on wavelet and Discrete Cosine Transform (DCT). In this paper, an efficient image compression scheme is proposed, based on a common encoding transform scheme; It consists of the following steps: 1) bi-orthogonal (tab 9/7) wavelet transform to split the image data into sub-bands, 2) DCT to de-correlate the data, 3) the combined transform stage's output is subjected to scalar quantization before being mapped to positive, 4) and LZW encoding to produce the compressed data. The peak signal-to-noise (PSNR), compression ratio (CR), and compression gain (CG) measures were used to perform a comparative analysis of the performance of the whole system. Several image test samples were used to test the performance behavior. The simulation results show the efficiency of these combined transformations when LZW is used in the field of data compression. Compression outcomes are encouraging and display a significant reduction in image file size at good resolution.

KEYWORDS: Wavelet Decomposition, DCT De-correlation, Scalar Quantization, String Table Encoding

1. Introduction

Images demand a lot of storage space, a lot of transmission bandwidth, and a lot of transmission time since they contain a lot of information. To reduce the number of bits required to represent an entity to match the actual situation, it is beneficial to compress the image by keeping only the information necessary to rebuild the image [1]. Data compression is a method for reducing redundant data representations, which lowers the need for data storage and, in turn, lowers communication costs. Increasing the capacity and transmission bandwidth of the storage media is comparable to decreasing the amount of storage required. Therefore, creating effective compression methods will remain a design problem for advanced multimedia applications and communication systems. Redundancy and information are combined to represent data and to appropriately evaluate the meaning or purpose of the data, information is a part of data and must be permanently kept in its original form [2]. Redundancy is the part of the data that can be eliminated when it is not required or reinserted to help analyze the data when it is required. To produce the original data in its original form, the redundancy is typically reinserted. Data compression is the practice of reducing data redundancy. Decompression of the data is the process of reducing redundancy in data representation so that it can later be reinserted to recover the original data [3, 4].

The goal of this work is to develop a color image compression system that is effective and efficient and is based on wavelet transformation and DCT. The image is split into four subbands where the wavelet processing is applied. For a specified number, the wavelet transform is repeated. After then, each subband is split up into a set of blocks, and each block is subjected to a DCT transformation. For each block, adaptive scalar quantization was used. By taking advantage of the fact that these high-frequency blocks can be treated

separately from low frequencies to produce better compression, the level of the quantization values varies according to the block feature, whether it is high frequency detailed blocks or low frequency correlated blocks. LZW is used to compress the data in the end. Compression ratio (CR), peak signal to noise ratio (PSNR), compression gain (CG), and encoding and decoding times are frequently used to estimate an image compression system's efficiency.

2. Literature Review

Review of the compression methods using the DCT section (2.1) and wavelet transformation section (2.2).

2.1. Image Compression with DCT

In [5] the authors suggested image compression strategies employing the DCT method with various blocks and quantization methods for lowering the blocking artifacts in reconstruction images. The maximum image dimension is divided into a maximum block size in the suggested approach, which then compresses the image. The proposed method divides the image into blocks (4×4, 8×8, 16×16, and 32×32). A PSNR score is produced using different quantization matrices to compare the performance of the original and reconstructed pictures. Based on the data, it can be concluded that the restored image becomes deformed as the quantization matrix's maximum value lowers. According to [6], the RGB to YCbCr color transformation process is used to carry out the proposed compression technique. Second, blocks are divided into the edge and non-edge blocks using canny edge detection. Each Y, Cb, and Cr color variable is compressed, quantized, and coded by the (DCT) method using adaptive arithmetic coding. The fast JPEG image compression technique based on DCT was proposed by [7]. The algorithm describes how to encode and decode images for JPEG. The image's encoding component can use JEPG to process images in the BMP format and compress them into binary files for real-time storage. The related decoding program can decompress the image. Additionally, the JPEG format can be used to encode a static image, and the color RBG of the JPEG image can be transformed into brightness y, Chroma Cr, and CB, which can efficiently minimize Chroma data and achieve compression. This is possible since human vision is not sensitive to Chroma.

2.2. Image Compression with Wavelet

To produce better-decompressed image output than the compression approach DWT+DCT [8], the authors introduced the Hybrid Integer Wavelet Transform (IWT) and Discrete Cosine Transform (DCT). In comparison to DWT-based and hybrid DWT DCT-based image compression approaches, the proposed combination

IWT + DCT-based compression methodology decreases fractional loss and hence offers a higher image quality of the decompressed image on high compression ratios. According to [9] the proposed approach begins by separating the image into sub-images and uses a high-level discrete wavelet transform, multiple levels of compression are used. With high-quality reconstructed images, the Huffman code with non-uniform Quantizer has also been employed to reduce the compression data rate. The suggested method's encouraging simulation results met the most important criteria, which are represented by the great image quality and a high image compression ratio. As an illustration, the PSNR and compression ratio (CR) of the Lena image achieved by the proposed approach simulation were 42.4094 dB and 47.5435, respectively. In [10] for effective and economical image compression, the discrete wavelet transforms (DWT) based on HAAR wavelets is used. Since the coefficient of HAAR DWT is either 1, or -1, it offers a simple method of compression. The temporal and frequency analysis employs wavelet transforms. After three levels of decomposition, a greater compression ratio is obtained in this paper. By taking into account both the image's overall quality and specific visual elements, the results are encouraging.

3. Image System Model

Image compression algorithms have been used with four connected stages in the suggested compression system to produce a high compression ratio with high image quality. A. Load image file, B. Transform Coding, C. Quantization, and D. Entropy Encoder are the steps in this process. To acquire the image data, the load image file is first used. Second, an appropriate transform (DWT and DCT) is done. Thirdly, the results are subjected to a scalar quantization operation to eliminate any psycho-visual redundancies that may still exist. It should be noted that the quantization is performed just once after applying both transforms. After mapping quantization values to positive numbers, LZW coding is used to code the data. Figure 1 indicates the structure of the system model; the following sections go into more depth about each stage of the system.

3.1. Load Image Data

The essential information of the image, as well as the data for the three red, green, and blue bands, are obtained by reading the image data.

3.2. Transformation Coding

In this stage, the image data is converted from the time domain to the frequency domain using the bi-orthogonal (Tap 9/7) wavelet transform and Discrete Cosine Transform (DCT).
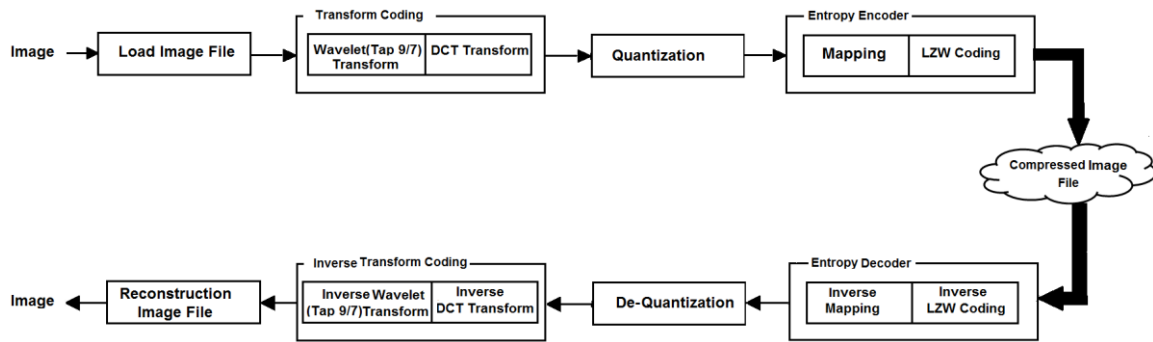
Figure 1: The System Structure

- Discrete Cosine Transform (DCT): The choice of this method as the JPEG standard has made it the most widely used image compression approach over the past few years [11]. A lossy compression technique called discrete cosine transform transforms NxN blocks from the spatial domain to the DCT domain. Concerning the visual quality of the image, the discrete cosine transform (DCT) assists in dividing the image into components (or spectral sub-bands) of varying relevance [12].

- Wavelet Transform: The wavelet transform has emerged as a key technique for image compression. Wavelet-based coding significantly improves image quality at high compression ratios, primarily because wavelet transforms have higher energy compaction properties [13]. The wavelet transform procedure is a straightforward idea. To replace the original transformed image, four new sub-images are created. Each sub-image is one-fourth the size of the original [14].

3.3. Quantization

Because it uses fewer bits to hold the transformed coefficient, quantization is regarded as the main source of the compression process. The quantizer reduces the accuracy of the transformed coefficient values because quantization is a many-to-one mapping [14]. In the quantization process, each coefficient in the fixed block DCT array is divided by a corresponding element Q_s that is generated adaptively using the equation [15]:

$$DCT_Q(x, y) = round\left(\frac{DCT(x,y)}{Q_s}\right) \quad (1)$$

Where the Q_s is calculated by the following equations:

$$Q_s = \begin{cases} Q_0 & \text{for DC coefficient} \\ Q_1 \times (1 + \alpha(u, v)) & \text{for AC coefficients} \end{cases} \quad (2)$$

3.4. Entropy Encoder

Use the right set of entropy encoders to effectively reduce any statistical redundancy that may be present in the resulting converted data. The mapping to positive and LZW are utilized at this step.

- Mapping to positive: Each positive value is transformed into an even number in the mapping stage, whereas each negative element's value is transformed into a positive odd number. The straightforward mapping equation is shown below [16] can be utilized to apply this conversion:

$$m_{out}(i) = \begin{cases} 2V(i) & \text{if } V(i) \geq 0 \\ -2V(i) + 1 & \text{if } V(i) < 0 \end{cases} \quad (3)$$

- Lempel Ziv Welch (LZW): Conceptually, LZW encoding is quite straightforward. The goal is to generate a dictionary (a table) of the strings used during the communication session at the beginning of the coding process. To decrease the amount of data communicated, previously encountered strings might be substituted by their index in the dictionary if both the sender and the receiver have a copy of it [17].

4. Proposed Compression System

One of the most helpful uses of this system is transform-based compression, which enables the effective transmission, storage, and display of images that would otherwise be impossible. The processes that the image goes through to be compressed are as follows:

- Red, Green, and Blue band values are calculated by reading the color image.
- Each band is subjected to the bi-orthogonal 9/7 wavelet transformation, which separates the band data into the (LL, LH, HL, HH) coefficients.
- Each subband has a certain type of image data. Depending on the value of the parameter (i.e., N_{pass}) for the number of wavelet transform passes, which the user has previously defined, the transform process may be repeated.
- Creating a set of pointers that denote the beginning (be) and ending (ed) of each subband of the wavelet coefficients.
- Each subband's wavelet coefficients are divided into blocks of (N×N). After that, each block is handled independently until the final one.

- Using the DCT transform, the data of each block (i.e., each subband of the wavelet coefficients) is independently deconstructed.
- Because the results of wavelet-DCT coefficients are real-valued, they must first be quantized to increase compression. Equations [1, 2] are used to apply uniform scalar quantization to the converted wavelet-DCT coefficients of each created block.
- To simplify the coding procedure for the following phase, equation [3] is used to map the sequence elements to be positive values.
- Encode the mapping data using the LZW compression algorithm to obtain compressed data.

4.1. Decoding

Decompression works in reverse of the steps involved in image compression and aims to restore the original image without compression. Where it contains LZW decoding, mapping to negative, dequantization, inverse DCT for each block, inverse wavelet transform, and reconstructed image data. The decoding method is shown in Figure 1.

5. Results

Various standard images were selected; all the images are square color scale images of size 256×256 pixels of 24 bit/per pixel shown in Figure 2. The effectiveness of the following system parameters was investigated:

- N_{pass} the number of wavelets passes, with range {2, 3, 4, 5}.
- Q_0 is the quantization parameter for DC coefficients, with range {1, 2,.., 20}.
- Q_1 is the quantization parameter for AC coefficients, with range {10, 11,.., 30}.
- Alpha (α) is the scaling factor for AC coefficients, with range {0.01, 0.02, .., 0.1}.
- Blks the block size, with range {4×4, 8×8, 16×16}.

The values of these variables were tested on the image, and the values of the compression ratio, compression gain, and the quality of the resulting image were changed. The results of these tests are shown in the Table 1. The proposed system in the Table 2, Table 3, Table 4, Table 5, and Table 6 was tested for the impact of the parameters. Increasing the values of these variables leads to an increase in the compression ratio and compression gain with a decrease in image quality. The PSNR value verifies that the compression and reconstruction of the original image are better even at level 2 of the wavelet transform, $Q_0=1$, $Q_1=20$, $\alpha=0.06$, and Blks=8×8. The results were also compared between the time of compression and the time of decompression of Lena's image in the Table 7, and the table showed good results.
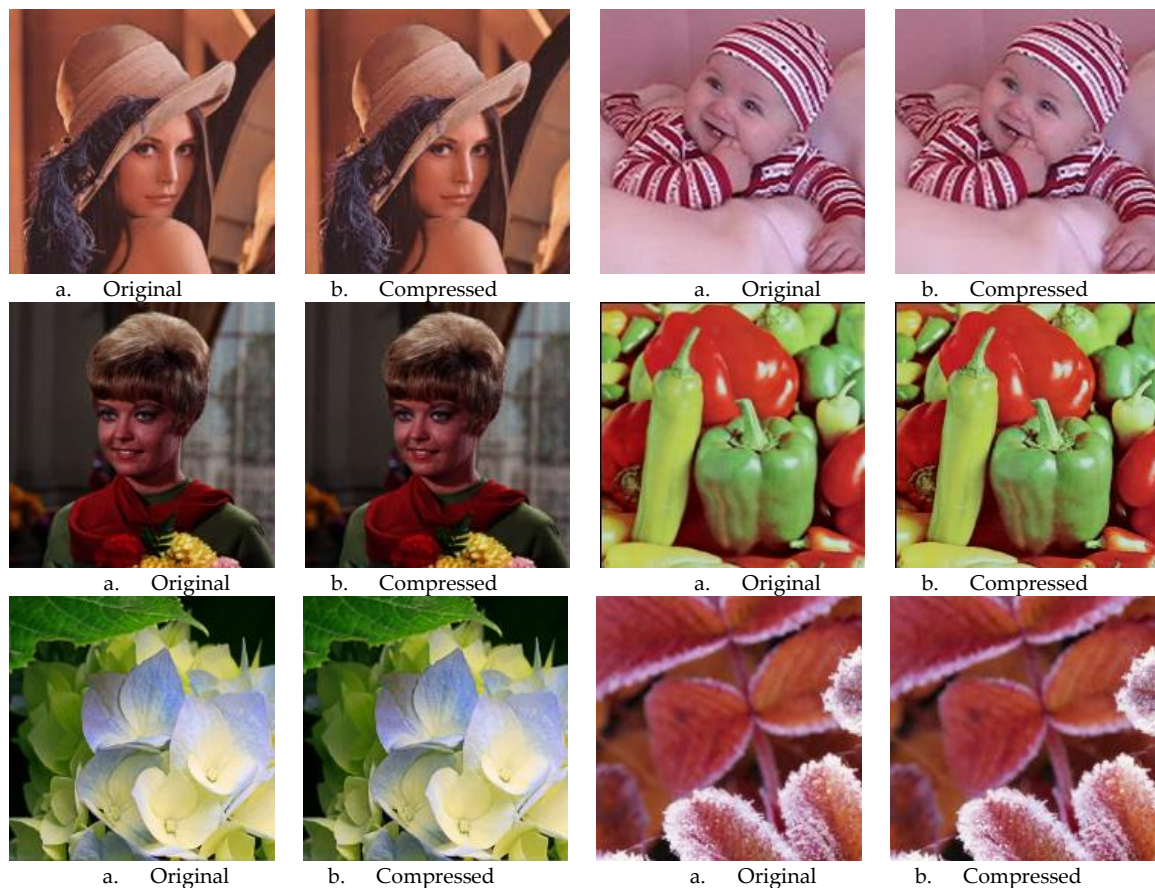

a. Original	b. Compressed	a. Original	b. Compressed
a. Original	b. Compressed	a. Original	b. Compressed
a. Original	b. Compressed	a. Original	b. Compressed

Figure 2: The Test Samples

Table 1: The Control Parameters' Default Values with the Best PSNR and CR

Samples	N_{pass}	Q_0	Q_1	α	CR	CG	PSNR
Lena	2	11	20	0.06	22.04	95.56	32.22
Child	2	23	21	0.06	15.48	94.83	32.03
Girl	2	24	20	0.06	19.60	95.18	32.15
Pepper	2	25	17	0.06	13.28	92.22	32.08
Flowers	2	25	17	0.06	16.97	93.31	32.19
Winter	2	18	21	0.06	18.84	95.15	32.00

Table 2: The effect of N_{pass} on CR and PSNR

N_{pass}	CR	CG	PSNR
2	22.039	95.56529	32.225
3	23.639	95.92692	30.269
4	24.304	96.06018	29.057
5	24.544	96.10596	28.168

Table 3: The Effect of Q_0 on CR and PSNR

Q_0	CR	CG	PSNR	Q_0	CR	CG	PSNR
1	12.1	94.87	35.93	11	22.0	95.56	32.22
2	13.2	95.06	35.63	12	23.1	95.57	31.92
3	14.2	95.19	35.13	13	24.2	95.59	31.52
4	15.3	95.28	34.83	14	25.2	95.60	31.01
5	16.3	95.35	34.23	15	26.3	95.62	30.81
6	17.4	95.41	33.93	16	27.3	95.63	30.51
7	18.4	95.45	33.63	17	28.4	95.64	30.10
8	19.4	95.48	33.22	18	29.4	95.64	29.80
9	20.4	95.51	32.93	19	30.4	95.64	29.50
10	21.9	95.54	32.72	20	31.4	95.65	29.09

Table 4: The effect of Q_1 on CR and PSNR

Q_1	CR	CG	PSNR	Q_1	CR	CG	PSNR
10	15.2	92.15	36.67	21	22.8	95.75	31.95
11	15.9	92.70	36.04	22	23.6	95.92	31.69
12	16.7	93.16	35.45	23	24.4	96.08	31.44
13	17.5	93.58	34.91	24	25.1	96.21	31.20
14	18.3	93.96	34.45	25	25.9	96.35	30.98
15	19.0	94.30	34.02	26	26.7	96.47	30.77
16	19.8	94.59	33.60	27	27.5	96.59	30.56
17	20.6	94.88	33.23	28	28.3	96.70	30.37
18	21.4	95.12	32.87	29	28.9	96.80	30.12
19	21.8	95.35	32.53	30	29.6	96.90	30.02
20	22.0	95.56	32.22				

Table 5: The Effect of Alpha on CR and PSNR

α	CR	CG	PSNR	α	CR	CG	PSNR
0.01	17.170	94.35	34.04	0.06	22.0	95.56	32.2
0.02	18.943	94.64	33.64	0.07	23.8	95.73	31.7
0.03	19.755	94.92	33.26	0.08	24.5	95.90	31.5
0.04	20.536	95.16	32.89	0.09	25.2	96.03	31.1
0.05	21.254	95.36	32.55	0.1	26.9	96.17	31.1

Table 6: The Effect of Block Size on CR and PSNR

Blks	CR	CG	PSNR
4×4	16.939	94.64518	34.027
8×8	22.039	95.56529	32.225
16×16	24.103	96.68121	29.794

Table 7: The Encoding and Decoding Time in Second

Samples	ET	DT
Lena	0.209	0.12
Child	0.218	0.182
Girl	0.239	0.140
Pepper	0.233	0.170
Flowers	0.221	0.123
Winter	0.230	0.110

Based on PSNR and CR criteria, the suggested method's performance metrics for Lena's image have been contrasted with the situation of artworks in Table 8. When compared to earlier work, the results indicated a good compression ratio.

Table 8: Comparison with Previous Works

Article	Method	CR	PSNR
[15]	1. The image compression using; DCT and bi-orthogonal (tap-9/7) wavelet transform. 2. Compression using LZW coding. 3. Comparing the results between them.	20.18	32.02
[18]	1. The image is subdivided into blocks. 2. One-D DCT is performed for each block. 3. An adaptive scalar quantization is performed. 4. The zigzag scanning. 5. An adaptive shift encoder is utilized.	12.8	32.22
[19]	1. Fast DCT is used. 2. Removed most of the zeros and keeps their positions in a transformed block. 3. Arithmetic coding is performed rather than Huffman coding.	20.49	36.468
[20]	1. Each block of the image is represented with a first- or second-order two-dimensional polynomial.	6.9977	31.0126

2. The encoded block size of the image is variable. 3. The polynomial order and the encoded block size are determined dynamically depending on the value of a threshold. 4. A prefix code of two bits is used to differentiate the encoding states. 5. Uniform quantization is applied to the coefficient matrix.		
Proposed method	22.039	32.225

At the end, the previous work [15] which relied on performing the wavelet transform and DCT transformation separately on the images, then compressing using LZW and comparing the results, unlike this work, which relied on the wavelet transformation procedure, then taking the resulting subbands and performing the DCT transformation on them and then LZW compressing. This work was able to progress on the previous work in terms of compression ratio with the same image quality 32db, but in terms of time only, it was close to the time of the previous work.

6. Conclusion

This study used wavelet, DCT, and LZW approaches to create computationally efficient and effective lossy image compression algorithms. Where the results showed that in the previous research [15] the compression ratio is 20.18, which depended on the image compression using; DCT and bi-orthogonal (tap-9/7) wavelet transform, then compression using LZW coding. While in the current research, the compression ratio shows progress reached to 22.039. Therefore, the suggested approach quickly compresses the image. Regarding the quality of the reconstructed images and the preservation of significant image elements, encouraging findings were observed. The project involves applying the bi-orthogonal 9/7 wavelet transform compression, followed by using the DCT approach and comparing results across different input images. In terms of time compression and decompression, the effort has shown positive results. It demonstrated how changing the values of the parameters affects both the compression ratio, compression gain, and the image quality, because increasing these values leads to lowers the image quality while raising the compression ratio and gain. When compared to a variety of earlier works, the work demonstrated good compression results.

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