Coding of DWT Coefficients using Run-length coding and Huffman Coding for the purpose of Color Image Compression

Varun Setia, Vinod Kumar

Abstract—In present paper we proposed a simple and effective method to compress an image. Here we found success in size reduction of an image without much compromising with it's quality. Here we used Haar Wavelet Transform to transform our original image and after quantization and thresholding of DWT coefficients Run length coding and Huffman coding schemes have been used to encode the image. DWT is base for quite populate JPEG 2000 technique.

Keywords—lossy compression, DWT, quantization, Run length coding, Huffman coding, JPEG2000

I. Introduction

IMAGE compression is the application of data compression on digital images. In effect, the objective is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form.Images are great source of information .image compression is vast but challenging area in the field of image processing. There are three main reasons why present multimedia systems require that data must be compressed:

1) large storage requirements of multimedia data,
2) Relatively slow storage devices that do not allow playing multimedia data (especially video) in real-time, and
3) The present network bandwidth, which does not allow real-time video data transmission.

Images can be compressed in two ways-

1) Lossless compression and,
2) Lossy compression.

In first compressed image is same as original and in second we removed some unimportant information from the image. In this paper we used lossy compression approach for gray scale images. If we remove all the redundancies from the image, we can compress the image efficiently. Here psycho visual redundancy is removed by DWT, and coding redundancy is removed by Huffman coding.

The paper is organized as follows. Section II introduces the process of compression. Section III explains Experimental results and discussion. Finally, the conclusion is given in section IV.

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II. The Process of Compression

The block diagram given below describes the process of compression and each block is discussed accordingly here.

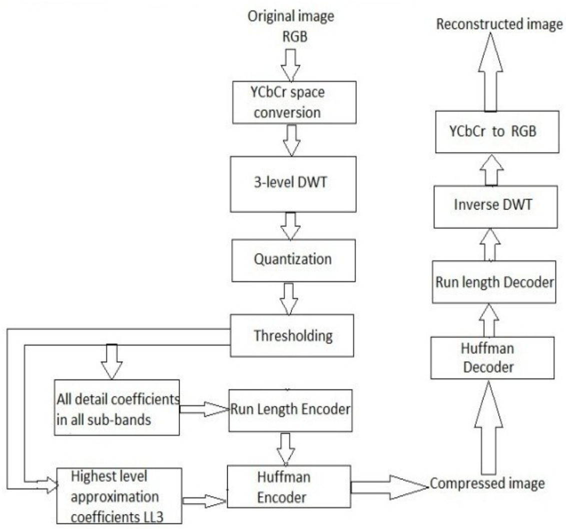

Fig. 1: The process of compression.

A. YCbCr space conversion

First we resolve our RGB image to YCbCr space. Y represents luminance information and Cb,Cr are chrominance information. The logic behind this process is that most of the image energy lies within Y component and also human eye is more sensitive towards luminance change than color changes. So is beneficial to work in YCbCr domain and to treat these three components separately.

B. Quantization and Thresholding

This step makes compression lossy. In this step we quantize all the coefficients. We fix the number of levels to represent the transformed coefficients.In quantization we divide all the coefficients by quantization step and round off them to nearest integer. Again we multiply coefficients with quantization step. As a result all the coefficients are grouped in different groups at different levels with level difference equal to quantization step. Quantization step is different for different sub-bands according to their range of values. Quantization step for a sub-band

$$Q_s = 2^{N-nl} N = \log_2 Max|C(i,j)| \quad (1)$$

And hard threshold for each sub-band is

$$Th = 2(N - n1) + 2(N - n1 - 1) \quad (2)$$

n1 can be varied from 0 to N-1. Here parent-children relationship of wavelet structure is exploited i.e. if parent coefficient value is lower than corresponding threshold then it is made to zero and its four children are also considered zero. This relationship is shown in Fig. 2.

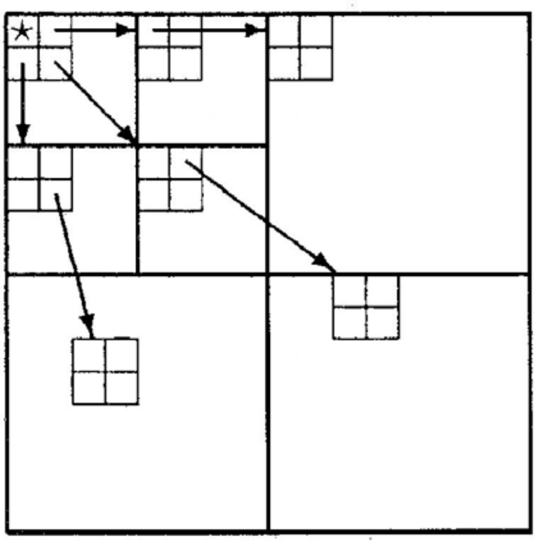

Fig. 2: The parent-children relationship of wavelet structure.

C. Encoding of DWT coefficients by Run-length encoder[18] and Huffman encoder

After introducing many zeros in sub-bands due to thresholding, We now encode our coefficients with RLE except the LL3 sub-band. Because LL3 sub-band doesnt have much long run of zeros. Now to convert redundant data into bit stream Huffman encoder has been used here. Huffman code is a prefix code ,good choice for source coding. It is minimum average length code.

D. Compressed Image

Here we get compressed image in form of a bit-stream. Its in non-visual format. This compressed image now can be transmitted for communication purpose.

E. Decompression

Decompression is the just inverse process of compression as indicated in block diagram.

F. Reconstructed Image

Compressed image is reconstructed with satisfactory quality through the process of decompression.

TABLE I: Initial Parameters for simulation

Image	Size	bpp	PSNR(dB)
'Lena.bmp'	512×512	24	∞
'Peppers.bmp'	512×512	24	∞
'House.tiff'	256×256	24	∞
'Zelda.tiff'	256×256	24	∞

TABLE II: Simulation results for image 'Lena.bmp'

Level-1 Decomposition		Level-2 Decomposition		Level-3 Decomposition	
bpp	PSNR(dB)	bpp	PSNR(dB)	bpp	PSNR(dB)
2.0218	30.1335	1.6424	30.7753	0.6305	26.7090
3.1354	31.5637	1.7006	31.2169	0.6739	27.2306
4.4949	31.9502	1.8224	31.4439	0.8118	27.3888

III. Experimental Results And Discussion

Four different standard color images have been taken for experimental purpose.Details of images taken for analysis are given in Table 1. Simulation results for different images are given in Table 2, Table 3, Table 4 and Table 5.

For measuring the originality of the compressed image Peak Signal to Noise Ratio (PSNR) is used, which is calculated using the formula:

$$PSNR(dB) = 10 \log_{10}(255)^2 / MSE \quad (3)$$

where MSE is the mean squared error between the original image f_{ij} and the reconstructed compressed image f'_{ij} of the size MN, which is calculated by the equation

$$MSE = \frac{1}{MN} \sum_{j=1}^{M} \sum_{i=1}^{N} [\{f'_{ij}\} - \{f_{ij}\}]^2 \quad (4)$$

Observing the Fig.3 which is based upon Table 2, Table 3, Table 4 and Table 5,we conclude that PSNR is inversely proportional to CR. In bpp v/s PSNR graph for all different

TABLE III: Simulation results for image 'Peppers.bmp'

Level-1 Decomposition		Level-2 Decomposition		Level-3 Decomposition	
bpp	PSNR(dB)	bpp	PSNR(dB)	bpp	PSNR(dB)
2.1615	28.8773	1.3826	28.3160	0.5670	25.4222
3.3546	29.5283	1.4276	28.8207	0.6265	25.8059
4.7306	29.6431	1.5510	31.4439	0.7419	25.8811

TABLE IV: Simulation results for image 'House.tiff'

Level-1 Decomposition		Level-2 Decomposition		Level-3 Decomposition	
bpp	PSNR(dB)	bpp	PSNR(dB)	bpp	PSNR(dB)
2.1314	30.3648	1.4850	30.9363	0.7352	27.2301
2.9787	31.5376	1.5502	31.6630	0.7647	27.6665
4.2098	31.8930	1.6620	31.8955	0.8740	27.7770

TABLE V: Simulation results for image 'Zelda.tiff'

Level-1 Decom-position		Level-2 Decom-position		Level-3 Decom-position	
bpp	**PSNR(dB)**	**bpp**	**PSNR(dB)**	**bpp**	**PSNR(dB)**
2.0593	29.5351	1.3193	29.2404	0.5277	27.7292
2.9295	30.1331	1.4073	29.7187	0.5631	27.3267
4.0890	30.1660	1.5162	29.8762	0.6924	27.4743

TABLE VI: Comparison with existing method (.jpg)

Image	Proposed Method			.jpg		
	bpp	**PSNR(dB)**	**CR**	**bpp**	**PSNR(dB)**	**CR**
Lena	1.8224	31.4439	13.66	2.1583	34.7628	11.11
Peppers	1.5510	28.9434	15.47	2.5045	31.3307	9.58
House	1.6620	31.8955	14.44	2.1622	32.5432	11.10
Zelda	1.5162	29.8762	15.89	2.1820	34.4299	10.99

images a sharp change in slope is observed ,It is the point where level of wavelet decomposition of an image changes from 2 to 1. At first level of decomposition 'bpp' is more than higher levels,reason being that approximation coefficient or LL sub-band requires more number of bits than other sub-bands. As we decompose LL sub-band further, total number of bits required decreases, with slight reduction in image quality. Refer to Fig.3, it is obvious that proposed method is uniform for different images. Only the location and slope of valley is changed for different images. In this manner, proposed technique can be generalized.2nd order wavelet decomposition of image gives better trade-off between' PSNR' and 'bpp' for proposed technique. We achieved higher CR for images at third level of wavelet decomposition of image. Highest CR achieved with proposed method is 45.48 for image 'Zelda.tiff' (PSNR 26.7292 db,bpp 0.5277)(Table 5). We see that quality of reconstructed images is satisfactory with reduced size.Also there is not much difference in important information content

TABLE VII: Comparison with existing method (CBTC-PF [5])

Image	Proposed Method			CBTC-PF		
	bpp	**PSNR(dB)**	**CR**	**bpp**	**PSNR(dB)**	**CR**
Lena	1.8224	31.4439	13.66	1.17	31.93	20.51
Peppers	1.5510	28.9434	15.47	1.50	30.15	16
House	1.6620	31.8955	14.44	1.20	31.79	20
Zelda	1.5162	29.8762	15.89	1.12	31.31	21.4286

TABLE VIII: Comparison with existing method (CDABS [4])

Image	Proposed Method			CDABS		
	bpp	**PSNR(dB)**	**CR**	**bpp**	**PSNR(dB)**	**CR**
Lena	1.8224	31.4439	13.66	0.8101	31.97	29.62
Peppers	1.5510	28.9434	15.47	0.809	30.059	29.66
House	1.6620	31.8955	14.44	0.8232	31.726	29.15
Zelda	1.5162	29.8762	15.89	0.8705	31.333	27.57

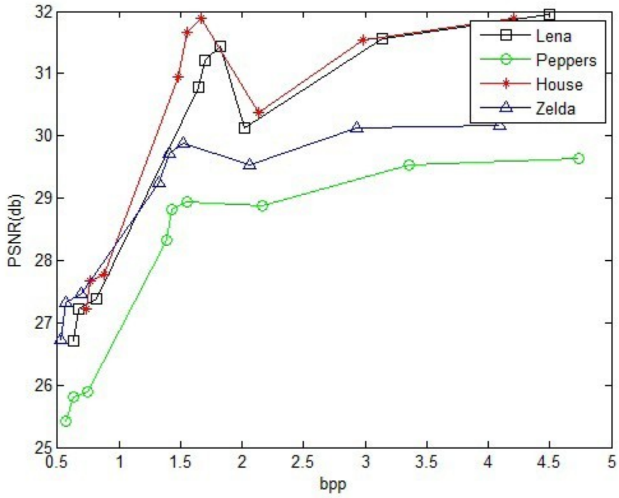

Fig. 3: Uniformity of proposed method over different images.

Fig. 4: Original and reconstructed image, 'Lena'(31.4439dB PSNR and 1.8224 bpp).

Fig. 5: Original and reconstructed image, 'Peppers'(28.9434dB PSNR and 1.5510 bpp).

of original and reconstructed images. Table 6 , Table 7 and Table 8 reveal that results for proposed method are in competence with results for existing methods. It is evident that DWT gives better result at high CR. For experimental analysis and observation, images have been saved on disk in *jpg format and then PSNR with original images were calculated. Refer to Table 6

IV. Conclusion

In this work, a new methodology has been proposed for image compression based upon wavelet transform. Our proposed

Fig. 6: Original and reconstructed image, 'House'(31.8955dB PSNR and 1.6620bpp).

Fig. 7: Original and reconstructed image, 'Zelda'(29.8762 dB PSNR and 1.5162 bpp).

method has comparable results with existing method with an ease of implementation. Proposed method can be used as a base model for research. Also experimental analysis is correlated with wavelet properties. DWT based methods are little bit faster than DCT based algorithms because there is no need to resolve the image into square blocks. Also HAAR Wavelet has been used in order to make implementation simple. There is less computational complexity with HAAR Wavelet transform. Use of Run-length encoding is quite logical choice because it compresses long run of redundant symbols very efficiently. Run-Length Encoder gives lossless representation of data with reduced number of bits. Use of Huffman encoder makes compressed data ready for transmission in the form of bit-stream.

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