DHT Based JPEG Image Compression Using a Novel Energy Quantization Method

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Abstract- **DCT based JPEG is an accepted standard for lossy compression of still image. DHT is a real valued transform whose forward and inverse transforms are same except for an inclusion of a scale factor in the inverse transform. In this paper DCT is replaced by DHT to reduce the computational complexity of JPEG. Quantization is mainly responsible for the amount loss in the image quality in the process of lossy compression. Quantisation of the DHT transformed coefficients is quite difficult. A new quantization method is proposed in the present investigation that facilitates speeding up the coding and decoding procedure while preserving image quality. The image quality of the reconstructed image are very good which is verified through extensive simulation. In this paper with the proposed method there is no need of a dequatizer at the decoder side. This would enable reduction of hardware and would make the implementation much simpler.**

Index Terms — DCT, JPEG, DHT, Quantization, Dequantization, Signal energy, Energy Quantisation.

I. Introduction

Image compression refers to minimization of number of bits required to represent an image. It is useful both for transmission and storage of information. The role of data compression is significant in broadcast television, remote sensing, military communication, radar, sonar, teleconferencing, computer communication and facsimile transmission. The compression of image for storage is needed for educational and business documents, medical images in computer tomography, magnetic resonance imaging, motion pictures, satellite images and geological survey. Compression of image data without degradation of image quality is possible because the image contains a high degree of redundancy. These are (i) special redundancy due to correlation between neigbouring pixels, (ii) spectral redundancy due to correlation between colour components and (iii) psychovisual redundancy due to properties of the human visual system. The higher the redundancy the higher is the achievable compression. An image compression system consists of three basic blocks such as the transformer, the quantizer and the coder. The transformer takes the raw image data and provides an image representation, which is more amenable for further processing. The quantizer generates a limited number of symbols that can be used in the representation of compressed image. It can be scalar or vector in nature. The coder assigns a code word to each symbol, which may be of fixed length or variable length.

In the literature many approaches have been proposed for image compression, including methods based on the wavelet transform [1], fractals [2] etc. Among them the Joint Photographic Expert Group (JPEG) [3,4] is a standard block transform based lossy compression technique. The JPEG scheme essentially employs the Discrete Cosine Transform (DCT) representation of the image. In this paper we propose a new approach to the JPEG compression and reconstruction scheme using a real valued Discrete Hartley Transform (DHT) [5,6] maintaining the other frames of JPEG unchanged. In other words the new scheme follows the same approach of the JPEG but employs a different transform. The objective is to obtain better reconstructed image from the modified JPEG scheme. We have compared the performance of both the DCT and the DHT based versions of the JPEG through computer simulation. The comparison has been made in terms of the Peak Signal to Noise Ratio (PSNR) present and bits per pixel (bpp) required to save the compressed image.

This paper is organized as follows. In the following section, presents the DCT based JPEG compression. In third section we proposed the new DHT based JPEG compression technique. Fourth section presents the proposed energy quantization & its application in the field of image compression is provided. The fifth section describes the experimental results and discussion. Last section ends the paper with some concluding remarks.

II. DCT Based JPEG Compression

The DCT based JPEG has been used as a standard for still image compression [7 - 8]. Fig. 1 and Fig. 2 shows the main processing steps of JPEG encoder and decoder respectively. The image is first partitioned into non overlapping blocks. Discrete Cosine Transform (DCT) [9 - 11], is applied to each of the non overlapping blocks to convert the gray level of pixels in spatial domain to coefficients in frequency domain. As a result the distribution of the energy of the image is redistributed into a small set of coefficients. The DCT coefficients are normalized by different scales, according to the quantization matrix as shown in the Table-I provided by JPEG standard, which is designed by conducting some psycho visual evidence. The JPEG quantizer is a bank of 64 linear (uniform) quantizers, one for each DCT coefficients as shown in Fig. 3. The ith quantizer is evaluated as

$$Y_i = \text{Round}(X_i / Q_i) \qquad (1)$$

where Q_i is the i'th quantization step size, X_i is the input where as Y_i is the scaled and quantized version of X_i. The JPEG decoder dequantizes Y_i to obtain a quantized version of X_i using $X' = Q_i * Y_i$. After quantization the quantized coefficients are arranged in a zigzag order as a result all the coefficients are arranged in lowest to highest spatial frequency.

Then any lossless coding techniques such as Run-length coding, Arithmetic coding, or Huffman coding applied to further compress the data. The decoding process is just the inverse process of encoding process shown in Fig. 2.

III. DHT Based JPEG Compression

DHT is a real valued transform whose forward and inverse transforms are same except for an inclusion of a scale factor in the inverse transform. DHT is a real valued transform whose forward and inverse transforms are same except for an inclusion of a scale factor in the inverse transform. Besides, the DHT can compute both convolution and the DFT efficiently. The memory requirement to compute both the forward and inverse DHT is about half as those of the DCT. The transform coefficients using the 2D DHT of a block of pixels $x(m,n)$ may be obtained as

$$X(k,l)=\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}x(m,n)\left[\cos\left(2\pi\left(\frac{km}{M}+\frac{ln}{N}\right)\right)+\sin\left(2\pi\left(\frac{km}{M}+\frac{ln}{N}\right)\right)\right] \quad (2)$$

where $k = 0,1,...M - 1,\ l = 0,1,... N - 1$

In the reconstruction part, the 2D Inverse Discrete Hartley Transform (IDHT) is employed. It may be mentioned here that the IDHT may be computed from eqn. 1 by replacing $x(k,l)$ in place of $x(m,n)$ and introducing a scale factor $\frac{1}{MN}$.

In the present work we have attempted the use of the DHT in JPEG to find out whether the new version of the JPEG can provide equivalent performance as that of the conventional one. The coding and decoding process is same as that of JPEG as shown in Fig-1 and Fig-2, only the difference is the DCT and IDCT block will be replaced by DHT and IDHT. The choice of QM and the multiplier greatly influence the performance of the JPEG scheme of image compression and reconstruction. While replacing the DHT in the JPEG framework, care should be taken in choosing proper QM. DHT transformed coefficients do not follows the zigzag scanning; instead they follow one special scanning order as shown in Fig. 4. So the designing of the QM matrix is quite difficult in this case. To eliminate these difficulties the quantisation techniques a new quantisation technique is proposed and tested for different images.

IV. Energy Quantization

A signal is most often considered as a function of varying amplitude through time, it seems to reason that a good measurement of the strength of a signal would be the area under the curve. However this area may have a negative part. This negative part does not have less strength than a positive signal of the same size (Fig. 7). Squaring the signal amplitudes gives rise to the energy contribution by the amplitude, adding all the signals will provide the total energy of the signal.

$$E_t = \int_{-\infty}^{\infty} (|f(t)|^2)dt \quad (3)$$

This technique of energy calculation has been applied to calculate the energy of the transformed coefficients of the image block, where each transformed pixel values are considered as the amplitude of the image signal. Taking the square of each transformed coefficients and taking the sum gives rise to the energy content in that block. Than a threshold value considered for elimination of the transformed coefficients i.e. if the energy of the transformed coefficient is less than the threshold value than make that zero, otherwise keep the coefficient as it is. The threshold value is considered according to the user requirement, i.e. how much energy of the image user want to save. For higher compression and low quality, less transformed coefficients has to be stored i.e. maximum amount of the energy has to be discarded. For low compression and high quality, maximum amount energy has to be saved.

First the normalized energy of the transformed coefficients is calculated using the following equation,

$$E_n = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}x(m,n)^2 \quad (3)$$

where M and N are the width and length of the sample block and $x(m,n)$ is the transformed samples. Than according to the threshold value, i.e. a measure to know the contribution of the transformed sample to the normalized energy is considered. For higher compression this threshold value has to be increased. The DHT coefficient can be saved as it is, but the transformed coefficients/samples have been normalized to decrease the amplitudes. At the decoder the compressed data is dequantized and passed through the IDHT operation to reconstruct the image.

V. Experimental Results

In this section, the superiority of the proposed technique is demonstrated through computer simulations running on Microsoft Windows XP, Pentium IV, 2.4 GHz platform. The Peak Signal to Noise Ratio (PSNR) as in (4) is the metric used for comparison.

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

where

$$MSE = \frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(X_{ij} - X'_{ij}\right)^2 \quad (5)$$

Where X_{ij} and X'_{ij} are the original and reconstructed pixel values at the location *(i, j)* respectively, and $(M\times N)$ is the image size.

The programs are implemented using Matlab 7.1. Performance of the proposed scheme Fig. 5, Fig. 6 is evaluated on a set of test images namely, Lena, Baboon, Pepper, Gold Hill and Airport images seen in Fig. 8.

In Table-II, the performance of the proposed technique is compared with the lossy JPEG compression. Two different quantization matrixes Mat1 & Mat2 as shown in Table 1 has been considered for DCT based JPEG compression. A wide range threshold value has been simulated for the proposed technique, which is determined after calculating the normalized energy of each sub blocks. And according to the threshold value the image is compressed. In the Table-II, we present the result of threshold value ranging form 100% - 5% of the normalized energy. The experimental results shows that the PSNR value of the new technique remains in the same range as that of the existing JPEG method. The reconstructed images and the error images are shown in Fig. 9.

VI. CONCLUSION

In this paper, a new DHT based JPEG compression technique using energy quantization method is proposed to speedup the encoding procedure while maintaining an acceptable image quality. Some of the high frequency components of the transformed sub image are preserved in accordance to the quantization value. The edge properties of the image are well preserved. In the proposed method there is no need of a dequantizer at decoder side so hardware requirement will be less and implementation will be easier.

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TABLE - I
QUANTIZATION MATRIXES FOR JPEG COMPRESSION

MAT1

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

MAT2

80	60	50	80	120	200	255	255
55	60	70	95	130	255	255	255
70	65	80	120	200	255	255	255
70	85	110	154	255	255	255	255
90	110	185	255	255	255	255	255
120	175	255	255	255	255	255	255
245	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255

TABLE - II

COMPARISON OF PSNR IN dB AND BITS PER PIXEL (bpp)

		JPEG(DCT based)		JPEG (DHT based) With ENERGY QUANTIZATION					
IMAGE		MAT1	MAT2	100%	80%	60%	40%	20%	10%
Lena	PSNR	36.80	30.62	29.83	30.35	31.03	31.92	33.59	34.98
	bpp	0.691	0.193	0.501	0.546	0.607	0.688	0.844	0.958
Baboon	PSNR	28.23	23.42	25.55	26.09	27.05	28.40	30.01	32.98
	bpp	1.538	0.381	0.502	0.547	0.609	0.710	0.901	1.077
GoldHill	PSNR	33.58	28.65	29.22	29.68	30.24	31.11	32.69	34.00
	bpp	0.876	0.205	0.635	0.701	0.784	0.911	1.107	1.293
Pepper	PSNR	34.74	30.09	29.13	29.60	30.18	31.02	32.55	33.85
	bpp	0.700	0.197	0.502	0.547	0.609	0.710	0.901	1.077
Airport	PSNR	28.69	24.58	25.32	25.80	26.53	27.48	29.56	30.80
	bpp	1.234	0.280	0.749	0.856	1.030	1.251	1.624	1.826

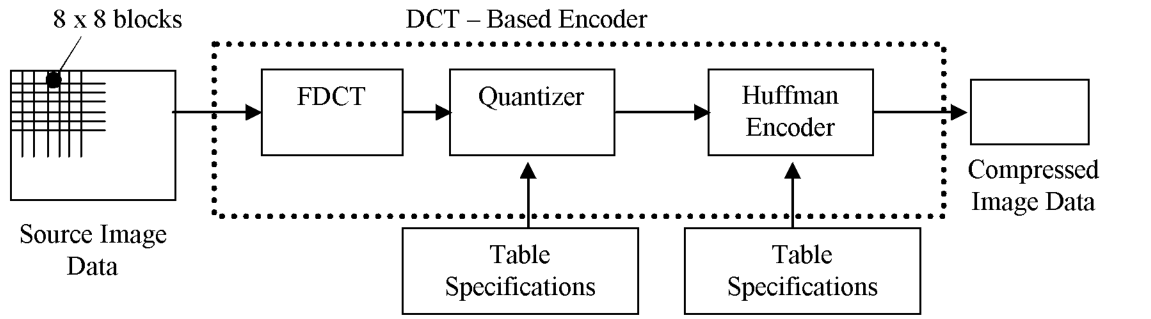

Fig 1. DCT-Based JPEG Encoder Processing Steps

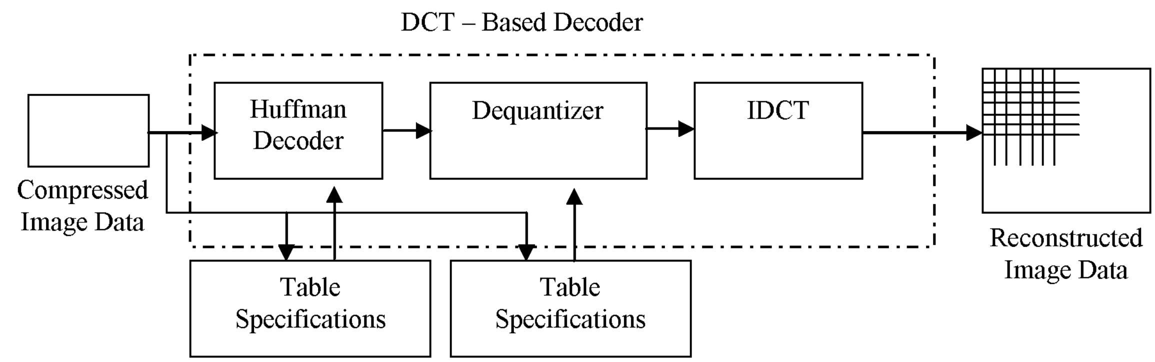

Fig 2. DCT-Based JPEG Decoder Processing Steps

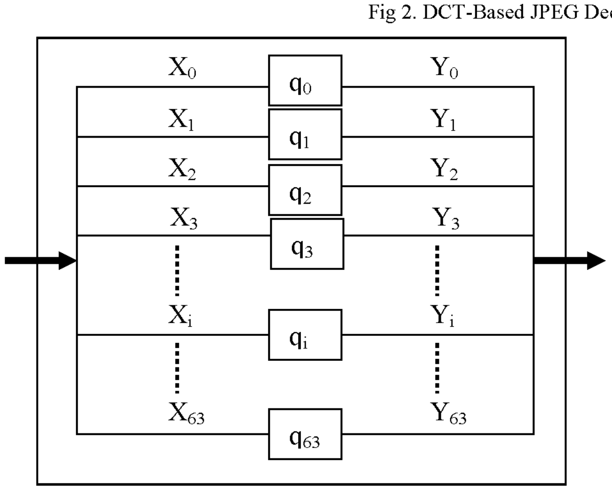

Fig 3. The JPEG Quantizer

1	2	4	6	8	10	12	14
3	16	17	19	21	23	25	27
5	18	29	30	32	34	36	38
7	20	31	40	41	43	45	47
9	22	33	42	49	50	52	54
11	24	35	44	51	56	57	59
13	26	37	46	53	58	61	62
15	28	39	48	55	60	63	64

Fig 4. Scanning order of DHT coefficient

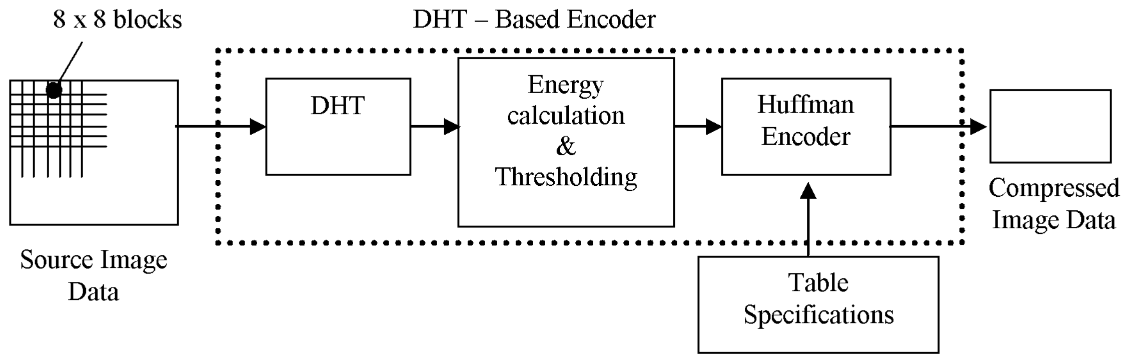

Fig 5. DHT-Based Encoder Processing Steps with energy quantization

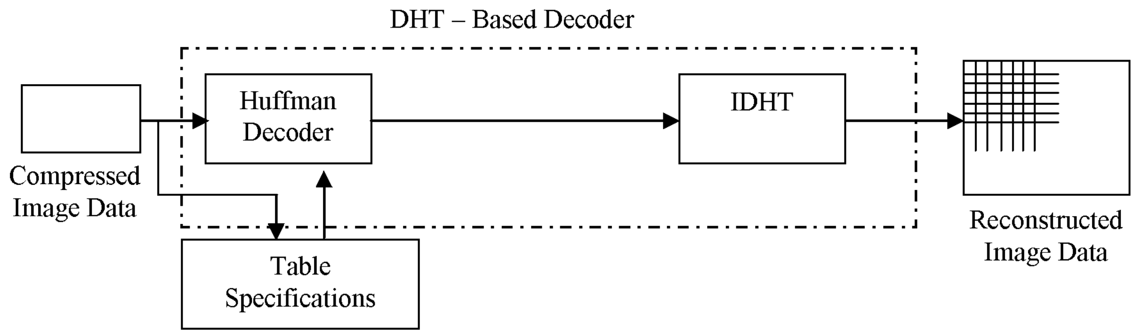

Fig 6. DHT-Based Decoder Processing Steps with out dequantization

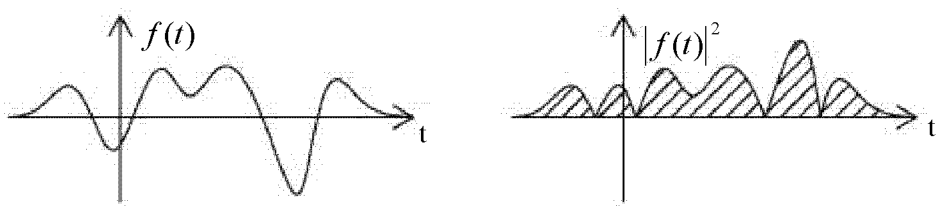

Fig 7. Original Signal and Signal Energy

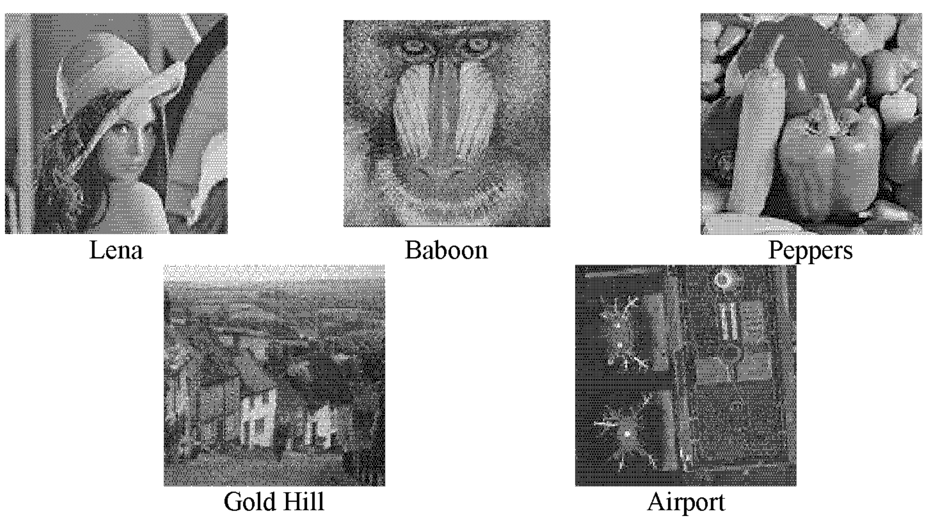

Fig 8. Test images used for experiments. Each image is 512 x 512 in size

Fig 9. (A, C)Decoded images using JPEG quantization matrix Mat1 & Mat2
(B, D) Error images of JPEG quantization matrix Mat1 & Mat2
(E, G, I, K, M, O)Decoded images using proposed Tech for Quantization value 10%, 20%,40%,60% , 80%,100%
(F, H, J, L, N, P)Error images using proposed Tech for Quantization value 10%, 20%,40%,60% , 80%,100%