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Performance Analysis of Image Compression Using Discrete Wavelet Transform

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Abstract— The main objective of source coding is to represent the symbols or messages generated from an information source in a suitable form so that the size of the data is reduced. In image compression we use JPEG where huge number of zero is generated in medium and high frequency region of transformed image using the combination of DCT (Discrete Cosine Transform) and quantization. This is required to reduce the run length coding of an image. The process is lossy compression but provide good illusion at a glance. In this paper we use Haar wavelet for image compression. Haar Transformation with an idea to minimize the computational requirements by applying different compression thresholds for the wavelet coefficients and these results are obtained in fraction of seconds and thus to improve the quality of the reconstructed image. In the results reconstructed image having high compression rates and better image quality.

Keywords— Filter bank, Mask matrix, MSE, DWT, JPEG, DCT, GIF, RGB, PSNR, Compression ratio and Spectral components Haar wavelet.

I. INTRODUCTION

The aim of an image compression technique is to reduce redundancy of the image data in order to be able to transmit data in an efficient form. This results in the reduction of file size and allows more images to be stored in a given amount of disk or memory space [1, 3]. Image compression techniques are categorized into two main types depending on the redundancy removal way, namely Lossless and lossy compressions [4, 15]. Lossless compression such as Huffman coding, Arithmetic coding, Run Length coding, Entropy Encoding, and Lempel-Ziv algorithm allow the original image to be reconstructed exactly from the compressed image with low compression rate. On the other hand, lossy image compression that characterized by degrade image quality, can't be reconstructed exactly from the compressed image. There is some degradation on image quality based upon the threshold that was used. However, the Compression Ratio (CR) is high. Examples of such compression are Vector Quantization, JPEG, Block Truncation coding, Fractal compression, Transform coding, Fourier-related transform, and Discrete Cosine Transform (DCT). Review on various lossless and lossy techniques can be found in [4, 6, 8].

Discrete wavelet transform is widely used in image processing, some of its applications are: pattern recognition, for example, font identification [1]; watermarking on image, extracting high frequency components of image using wavelet packet transform [2, 3]; biometric identifications [4, 5]; image de-noising [6, 7] etc. In this paper we are only concern about image compression based Discrete Wavelet Transform (DWT). There is a big trade-off among image compression, compression ratio and mean square error between original and recovered image. In lossy compression the compression ratio is high but for lossless compression the compression ratio is low therefore an intelligent decision is necessary in image compression specially to handle multimedia traffic in Internet. One common technique of image compression is JPEG where the original RGB image is converted to National Television System Committee (NTSC) whose constituents are luminance matrix Y and Chrominance matrix C of in-phase and quadrature components. Since human eyes are less sensitive to chrominance than luminance hence 4 pixels of C. and CQ matrices are averages to make the size of matrices halves. Each matrix is quantized by subtracting 128 from each pixel value then normalized by predefined quantization matrix. The DCT is applied on each 8x8 block which provides zeros on medium and high frequency components discussed in [8]. The DC components of blocks are stored using Differential Pulse Code Modulation (DPCM). Finally blocks are read in zigzag fashion and run-length code is applied on the data string.

Wavelet based image compression is more attractive than DCT of Joint Photographic Experts Group (JPEG) since DWT can represent different region of an image with different degree of resolution. JPEG 2000 adopts the concept of DWT based image compression [9, 11]. In this case two factors are considered: (a) coefficients with small value are dropped since their contribution in image reconstruction is little (b) low frequency components of an image (called approximate) are kept interact and high frequency components (called detailed) are control to make the image acceptable from viewer's point. In image processing, two dimensional wavelet transform is widely used with some threshold to preserve the most energetic coefficients for both de-noising and compression of image. For this purpose two dimensional filter bank of or wavelet packet transform of [2, 12, 13] is widely used.

II. HAAR IMAGE COMPRESSION AND CONSTRUCTION

Wavelets are functions generated from a single function by its dilations and translations. The Haar transform forms the simplest compression process of this kind. The Haar transformation matrix, T, is an orthonormal matrix as its rows are orthogonal to each other. That is the output Haar wavelet image, y, equals to TxT^T, where, x is the input image. An implementation of these operations is equivalent to the following filtering processes. Separates the high and low frequency portions of the image through the use of filters, then down sample by a factor of two. Multiple levels (scales) are made by repeating the filtering and decimation process on low pass outputs [8, 12, 14]. DWT have become a powerful tool for numerous types of applications such as signal compression, signal and numerical analysis because of its inherent time-scale locality characteristics. This leads to the researchers and scientists to develop various algorithms and theories to implement the DWT for numerous applications. The use of DWT is going on increasing specially in area of Image coding. DWT decompose the input image in a generalized fashion as shown below in Fig. 1. As it is known that images are present in form of matrix consist of rows and columns and for each decomposition level filtering is performed in two stages. At stage 1, Low Pass Filter and High Pass Filter are applied on the rows and at stage 2; same are applied on the columns of matrix. As a result, four sub bands of image LL, LH, HL and HH are formed. The sub band with low frequency components is termed as LL; also known as approximate image and other three with high frequency components are LH, HL and HH; collectively known as detail sub bands [12].

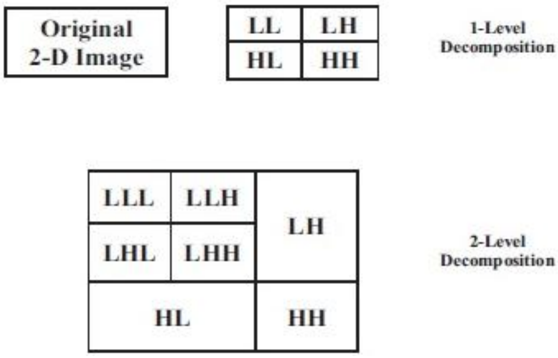

Fig.1: Two Level Decomposition of an Image

Let us consider the size of input image is M*M, and the size of details sub bands (LL, LH, HL, HH) is M/2*M/2. For 2-level of decomposition LL sub band will act as Input and the size of the three sub bands at 2-level decomposition is M/4*M/4. Hence, multilevel decomposition of 2-D image by DWT has been carried out in analogous manner [10].

III. ALGORITHM OF IMAGE COMPRESSION AND ITS RECOVERY

Let us compress the vector, V = [A(1) A(2) A(3), . . . A(N)] using Haar wavelet transform. Step-I: Generate V_1= [B(l) B(2) B(3),... ... . .. , B(N)]; Where B(i) = 0.5(A(2i-l)+A(2i) for i = 1, 2, 3, ... N/2 and B(N/2+i) = B(i)-A(2i) for i = 1,2,3, ... , N/2. Step-2: Keep the components B (N/2+i) for i = 1, 2, 3, ... N/2 fixed and apply step 1 on B(i) for i =1,2, 3, ... ,N/2. Step-3 Repeat the procedure until getting all the elements fixed. The original sequence can be recovered by reverse algorithm mentioned in [3]. In this paper we use the following algorithm of image compression based on the concept of 2D Haar wavelet transform of [13, 14],

1) Read the RGB image
2) Segregate R, G and B components
3) Create Haar matrix W of 8x8 shown below:

$$W = \begin{bmatrix} 1/8 & 1/8 & 1/4 & 0 & 1/2 & 0 & 0 & 0 \\ 1/8 & 1/8 & 1/4 & 0 & -1/2 & 0 & 0 & 0 \\ 1/8 & 1/8 & -1/4 & 0 & 0 & 1/2 & 0 & 0 \\ 1/8 & 1/8 & -1/4 & 0 & 0 & -1/2 & 0 & 0 \\ 1/8 & -1/8 & 0 & 1/4 & 0 & 0 & 1/2 & 0 \\ 1/8 & -1/8 & 0 & 1/4 & 0 & 0 & -1/2 & 0 \\ 1/8 & -1/8 & 0 & -1/4 & 0 & 0 & 0 & 1/2 \\ 1/8 & -1/8 & 0 & -1/4 & 0 & 0 & 0 & -1/2 \end{bmatrix}$$

4) Separate R component into 8x8 block where each component is represented as X.
5) Apply DWT on each block using: D= W x X x W'
6) Create a mask of 8x8 containing few 1 in the position of DC and low frequency region like:

$$M = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

7) Multiply each block of the R component by M and resultant block will be, Y = M x D
8) Apply IDWT on each block Y using, D_I = W' x Y x W

9) Repeat the operation of step 3 to 8 on G and B component of the image
10) Combine R, G and B component found from state-9
11) Display the image
12) Find mean square error between original and recovered image.

Comparing the original and recovered image we will find the following three parameters. The normalized mean square error (MSE),

$$MSE_N = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}|X_0(i,j) - X_r(i,j)|^2}{\sum_{i=1}^{N}\sum_{j=1}^{N}|X_0(i,j)|^2} \quad (1)$$

The Signal to Noise (SNR) in dB,

$$SNR = 10\log\left(\frac{1}{MSE_N}\right) \quad (2)$$

Peak Signal to Noise Ratio (PSNR) in dB,

$$PSNR = 10\log\left(\frac{255^2}{MSE}\right) \quad (3)$$

Where Mean Square Error (MSE) is

$$MSE = \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N}|X_0(i,j) - X_r(i,j)|^2 \quad (4)$$

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In order to test the proposed system performance; three Matlab standard colored images are selected. Three of them are 512x512 (8 bits/pixel) images. The algorithm has been implemented using Matlab language. The simulation shows that the MSE, the SNR, and the PSNR do not change much above the fifth level. This suggests that instead of decomposing the image to its highest level, which is one approximation coefficient, we stop at level six. Original images and the corresponding recovered images taking 42.8% zeros are shown in figure-2. Where the differences between original and recovered images are subtle and human eye can barely recognize them. Our aim is to introduce more zeros on the transformed image so that the advantage of run-length coding can be taken. The main region will be to detect the threshold percentage of zeros so that the image lies in acceptable position to an observer. In this context we select the test image-1, and corresponding results are shown in table-I. We can introduce 95% zeros in an RGB image observed from table-l and beyond that the distortion of an image becomes distinct. Human eye is more sensitive to DC and low frequency component of an image visualized from the pattern of the mask. In JPEG the high frequency components of each block is eliminated by quantization technique but here we eliminate them by force to reduce the complexity of the algorithm.

Fig.2: Test image-1 original and recovered image

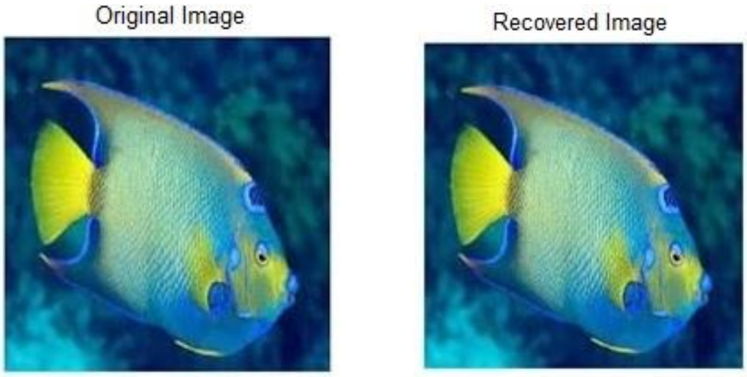

Fig.3: Test image-2 original and recovered image

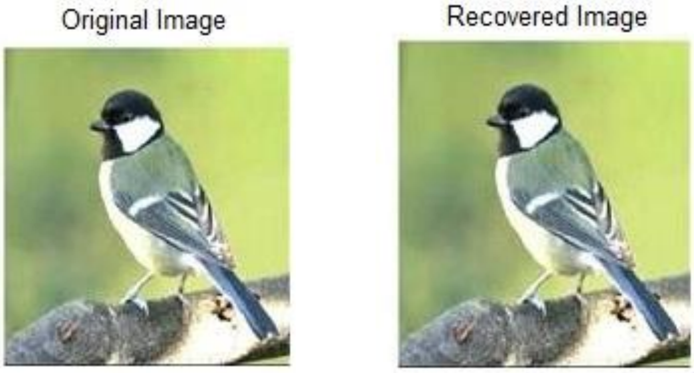

Fig.4: Test image-3 original and recovered image

The below table shows the comparison MSE, SNR in dB and PSNR in dB of the recovered test image-2.

Table 1: Compression of Recovered Images

Sl.No	Fraction of Zeros	MSE	SNR (dB)	PSNR (dB)
1.	0.428	0.062	13.024	58.462
2.	0.553	0.108	11.342	56.847
3.	0.674	0.164	8.724	55.287
4.	0.787	0.195	7.183	54.489
5.	0.865	0.226	6.841	52.816
6.	0.912	0.290	5.246	51.462
7.	0.984	0.351	4.483	49.638

We plot the MSE against fraction of zeros from the three images of fig.2 shown in fig. 5 and got the same results.

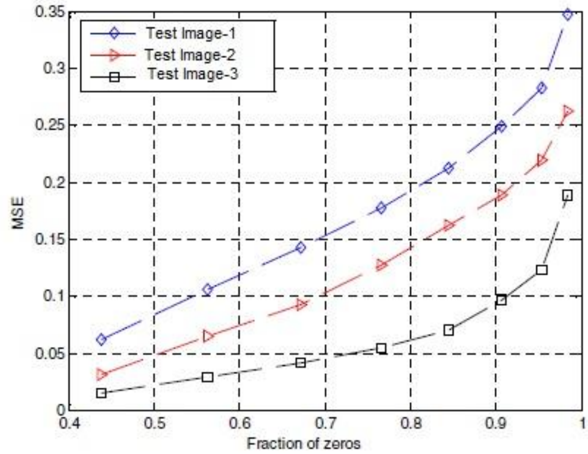

Fig. 5: Profile of MSE against fraction of zeros

We plot the SNR in dB against fraction of zeros from the three images of fig.2 shown in fig. 6 and got the same results

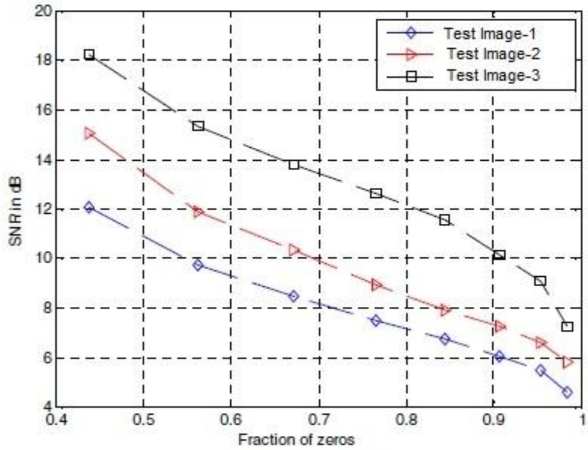

Fig.6: Profile of SNR against fraction of zeros

V. CONCLUSION

In this paper we analyzed lossy compression of an RGB image by 2D Haar DWT and recovered it by inverse operation and provide acceptable recovery at a glance till 90% of zeros on each block. The algorithm is much simpler than JPEG or JPEG 2000 hence the technique is applicable in pattern recognition of complicated image like biometric (human face, fingerprint, retina or manual signature) identification where the process time is the main concern.

The entire work can be extended using other wavelet matrix to make the comparison of performance even we can apply the algorithm for de-nosing operation of images.

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