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Analysis of JPEG DCT, Haar & Daubechies Wavelet, Fractal for Image Compression

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Abstract: **Image compression is a method through which we can reduce the storage space of images, videos which will helpful to increase storage and transmission process's performance. In image compression, we do not only concentrate on reducing size but also concentrate on doing it without losing quality andinformation of image. In this paper, we present the comparison of the performance of Discrete cosine transform JPEG, Discrete wavelet transform &wavelets like Haar Wavelet & Daubechies Wavelet Fractal Compression for implementation in a still image compression system and to highlight the benefit of these transforms relating to today's methods.The performance of these transforms are compared in terms of Peak Signal to noise ratio PSNR, Compression Ratio & Encoding Time etc.**

***Keywords*-DWT, DWT, SNR, MSE, Image Compression**

I. INTRODUCTION

In today's technological world as our use of and reliance on computers continues to grow, so too does our need for efficient ways of storing large amount of data and due to the bandwidth and storage limitations, images must be compressed before transmission and storage. For example, someone with a web page or online catalog that uses dozens or perhaps hundreds of images will more than likely need to use some form of image compression to store those images. There are several methods of image compression available today. This fall into two general categories: lossless and lossy image compression. With lossless compression [1-2], every single bit of data that was originally in the file remains after the file is uncompressed. All of the information is completely restored. The Graphics Interchange File (GIF) is an image format used on the Web that provides lossless compression. On the other hand, lossy compression reduces a file by permanently eliminating certain information, especially redundant information. When the file is uncompressed, only a part of the original information is still there (although the user may not notice it). The JPEG image file, commonly used for photographs and other complex still images on the Web, is an image that has lossy compression.

II. TRANSFORM CODING

Transform coding techniques [3] use a reversible, linear mathematical transform to map the pixel values onto a set of coefficients, which are then quantized and encoded. Transform coding relies on the premise that pixels in an image exhibit a certain level of correlation with their neighboring pixels. Consequently, these correlations can be exploited to predict the value of a pixel from its respective neighbors. Different mathematical transforms, such as DCT& DWT have been considered for the task & their description is as follows:

A. *Discrete Cosine transform*: A discrete cosine transform (DCT) [4] expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillatingat different frequencies. DCTs are important to numerous applications in science and engineering, fromlossy compression ofimages (where small high-frequency components can be discarded). In any transformedimage [5] as shown in figure 1, DC is the matrix element (1,1), corresponding to transform value X(0,0), high spatial X and Y frequencies correspond to high column and row indexes, respectively.

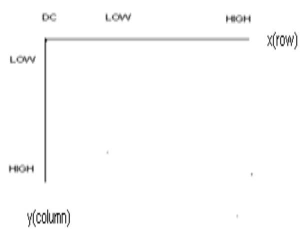

Figure 1:- Transformed image matrix, X columns denote horizontal spatial frequencies, Y columns denote vertical frequencies.

Procedure for DCT Based compression: Generally nature pictures/scenery arefound to have redundancy so to compress these images or to reduce the redundancy the following steps to be followed:

1. Convert the continuous/analog image to digital image that is in the pixel values.
2. For reducing redundancy divide the image into small blocks of either 4*4, 8*8, 16*16 matrix.

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3. Apply the suitable transformation to each block of whole image, we have applied DCT.
4. For the further Compression either apply Quantization process of some pixel values of the image.For quantization of 8*8 block we use this matrix

Quant=
[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]

and the quantized image matrix is given by=C=round (actual image matrix/quant)

5. For the reconstruction of the image we should apply inverse transformation to each block of the whole image.
6. Finally results can be compared by calculating the difference between the respective pixel values of original image & recovered image.
7. Also compression can be calculated to know the % of compression which is simply the ratio of the size of the image file before and after compression.

(B) Discrete Wavelet transform: A wavelet is waveform[6] of limited duration that has an average value of zero. Wavelets are localized waves and they extend notfrom -∞ to +∞ but only for finite time duration, as shown in Fig below. A wavelet as shown in figure 3(b) is a waveform of effectively limited duration that has an average value of zero.

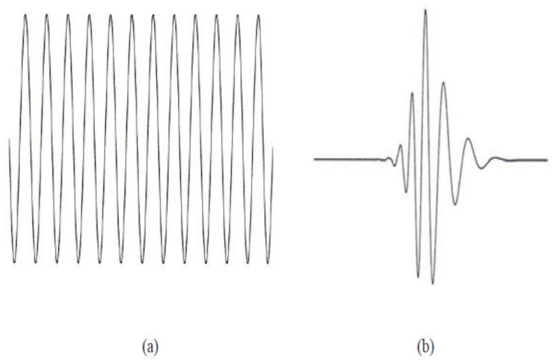

Figure3:- (a) A Wave (b) A Mother Wavelet

The basis of Discrete Cosine Transform (DCT) [7] is cosine functions while the basis of Discrete Wavelet Transform (DWT) is wavelet function that satisfies requirement of multiresolution analysis. DWT represents image on different resolution level i.e., it possesses the property of Multi-resolution. DWT [8]Converts an input image coefficients series x0,x1,xm into one high-pass wavelet coefficient series and one low-pass wavelet coefficient series (of length n/2 each) given by:

$$H_1 = \sum_{m=0}^{k-1} x_{2i-m} \cdot s_m(z)$$

$$L_1 = \sum_{m=0}^{k-1} x_{2i-m} \cdot t_m(z)$$

Where Sm (Z) and tm (Z) are called wavelet filters, K is the length of the filter, and i=0, [n/2]-1.In practice, such transformation will be applied recursively on the low-pass series until the desired number of iterations is reached as shown in figure 4

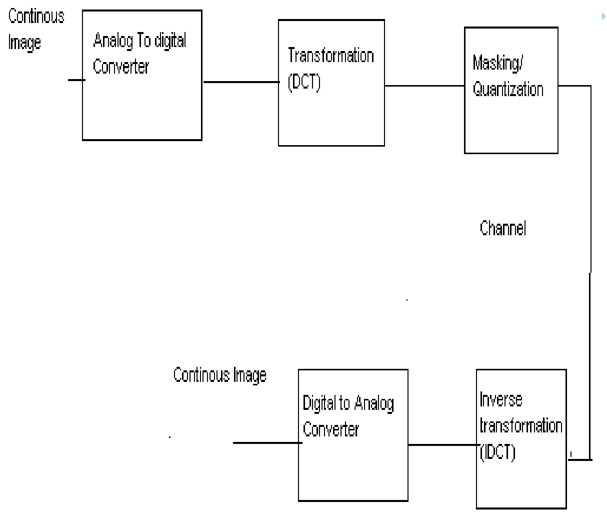

Figure 2:- Block Diagram describing the stages of compression & decompression of DCT

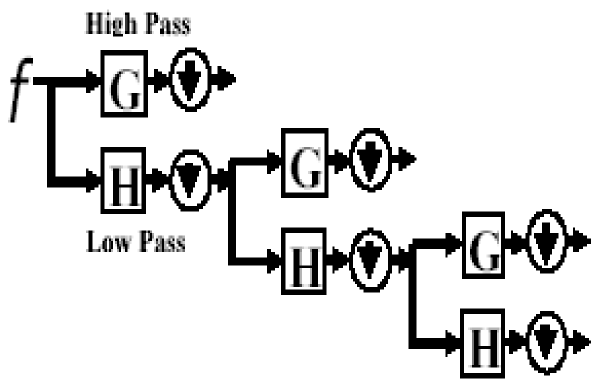

Figure 4:- Filter iteration Series

III. HAAR WAVELET

Any discussion of wavelets begins with Haarwavelet[8][9], the first and simplest. Haar wavelet isdiscontinuous, and resembles a step function. It represents the same wavelet as Daubechies db1.

The first DWT was invented by the Hungarian mathematician AlfredHaar. For an input represented by a list of numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated

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recursively, pairing up the sums to provide the next scale, finally resulting in differences and one final sum.

The Haar Wavelet Transformation is a simple form of compression which involves averaging and differencing terms, storing detail coefficients, eliminating data, and reconstructing the matrix such that the resulting matrix is similar to the initial matrix.[10]

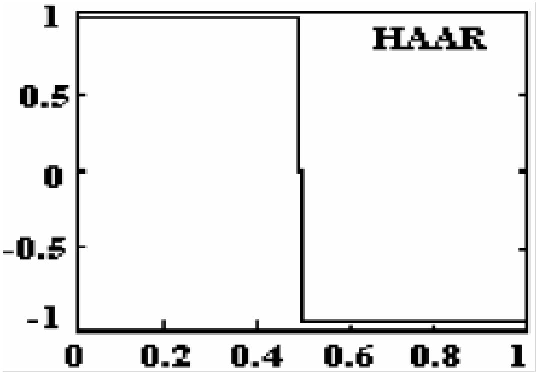

Figure 5:- Haar Wavelet

IV. DAUBECHIES WAVELETS

Ingrid Daubechies, one of the brightest stars in the world ofwavelet research, invented what are called compactly supported orthonormal wavelets — thus making discrete wavelet analysis practicable.The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet. The db1 wavelet, as mentioned above, is the same as Haar wavelet. Here is the wavelet functions psi of the next nine members of the family[8].

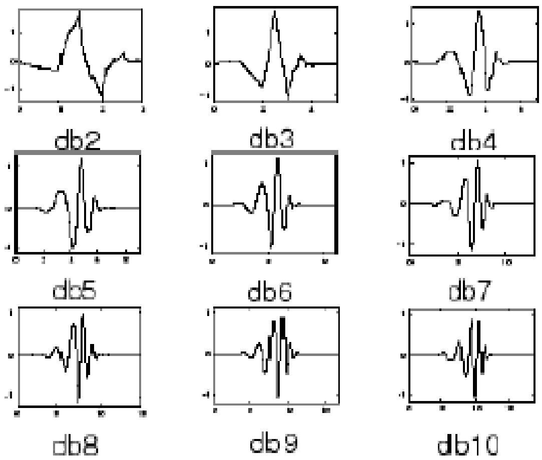

Figure 6:- Waveforms of various versions of daubechies wavelet

Procedure For Image Compression Using Discrete Wavelet Transform:

1. Read the image & convert the continuous image in to discrete pixel values.
2. Transformation: Apply 2 Dimensional DWT using haar&Daubechieswavelet over the image.
3. Threshold Detail Coefficients:For each level, a threshold is selected and hard thresholding is applied to the detail coefficients. Compression is based on the concept that the regular signal component can be accurately approximated using the following elements: a small number of approximation coefficients and some of the detail coefficients. This step basically provides compression to the image.
4. After that Compressed image is transmitted through Channel.
5. Inverse Transformation/ Reconstruction: Reconstruct an estimate of the original image by applying the corresponding inverse transform.
6. Display the resulting images and analyze the quality of the image.
7. Calculate MSE, SNR & Energy retained for corresponding reconstructed image.
8. Display and compare the various results like MSE, SNR and Compression ratio at different Threshold values.
9. The same process is repeated for various images and their performances are compared.

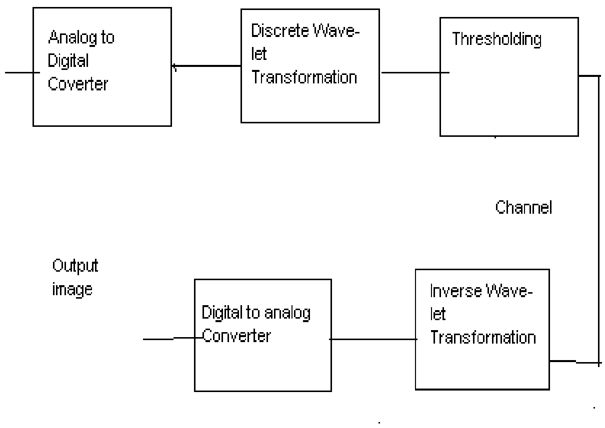

Figure 7:-Block Diagram describing the stages of compression & decompression of an Image using DWT.

(C) Properties of Transforms:

Some properties of these transforms which are of particular value to image processing applications are as follows:

1. Decorrelation: The principle advantage of image transformation[12] is the removal of redundancy between neighboring pixels. This leads to uncorrelated transform coefficients which can be encoded independently
2. Energy Compaction: Efficiency of a transformation [8][12] scheme can be directly gauged by its ability to pack input data into as few coefficients as possible. This allows thequantizer to discard coefficients with relatively small amplitudes without introducing visual distortion in the reconstructed image.
3. Orthogonality:Basis functions of these transforms[12] are orthogonal . Thus, the inverse transformation matrix of A is equal to its transpose i.e. invA=A^T

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V. RESULTS AND DISCUSSION

The coding of this paper is done in MATLAB 7.In this paper, we compared discrete cosine transform (DCT) &Haar& Daubechies wavelet of Discrete wavelet transform (DWT). The quality of a compression method could be measured by the traditional distortion measures such as the peak signal to noise ratio (SNR)
and compression ratio. We have compared the performance of these transforms on different images .
Figure 8 shows an image of Leena of size 512x512. This image is compressed and decompressed using Haar Wavelet Compression Technique. The encoding time is **0.3594** seconds and the size of the encoded text file is 351KB, and compression ratio achieved is of 48.5876%. The Histogram of this technique is also shown in figure.

Images	PSNR	Compression Ratio	Encoding Time (in seconds)
Leena	79.2024	48.5876	0.3594

Table 1: Performance of Haar Wavelet Techniques

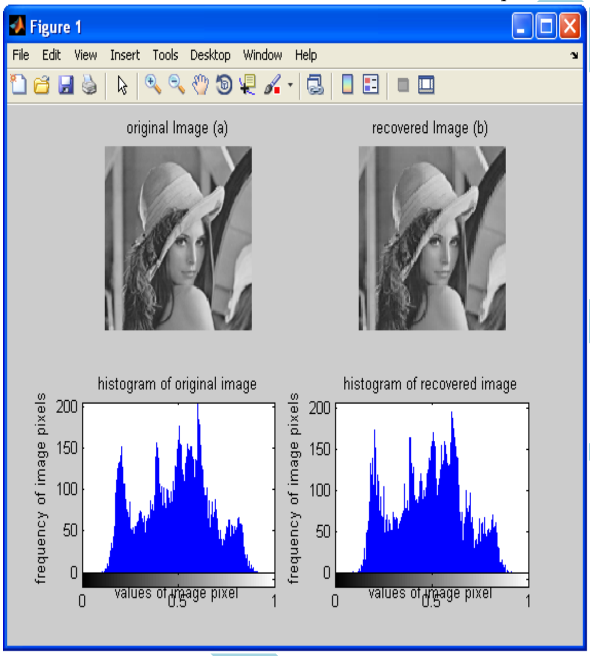

Figure 8: Implementation of Haar Wavelet Technique

Figure 9 shows an image of priyanka of size 512x512. This image is compressed and decompressed using Daubchies Compression Technique. The encoding time is **0.3594** seconds and the size of the encoded text file is 351KB, and compression ratio achieved is of 48.5876%. The Histogram of this technique is also shown in figure.

Images	PSNR	Compression Ratio	Encoding Time (in seconds)
Priyanka	82.4299	48.5876	0.3750

Table 2: Performance of Daubchies Techniques

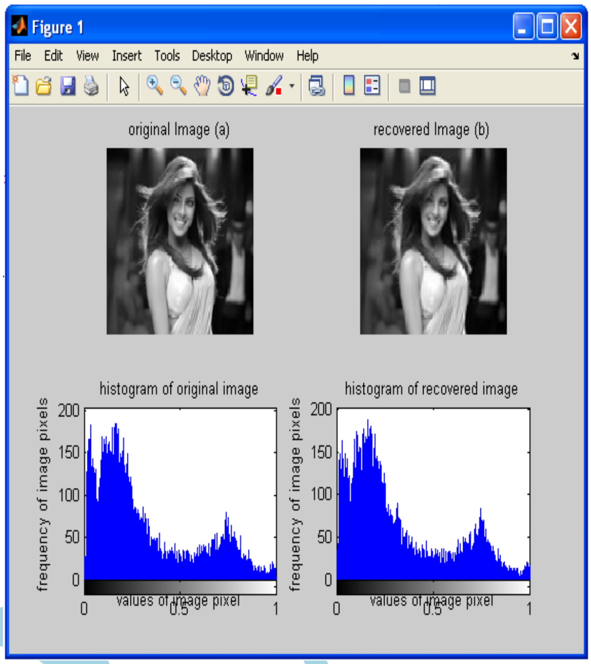

Figure 9: Implementation of Daubchies Technique

Figure 10 shows an original image and histogram of Sachin of size 512x512.

Image	Compression Ratio	PSNR	ENCODING TIME
Sachin	78.036	37.098	0.063

Table 3: Performance of JPEG Techniques

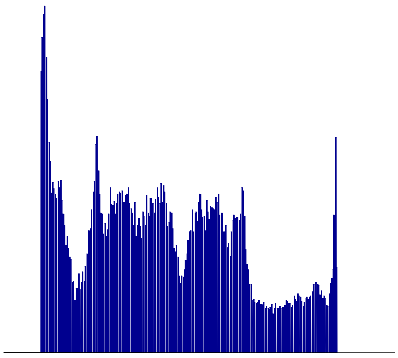

Figure 10(a) Histogram of Original Image

Figure 10(b) Original Image

Figure 11 shows reconstructed image and histogram of Sukanya of size 512x512

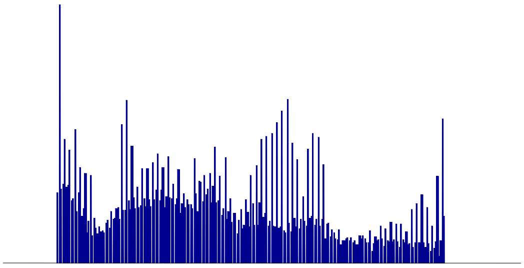

Fig 11(a): Histogram of reconstructed image

Fig 11(b) Reconstructed image

Fig 12 shows an image of mahi of size 512x512. This image is compressed and decompressed using Fractal Image Compression Technique in Wavelet Domain. The encoding time is **110.2030** seconds and the size of the encoded text file is 351KB, and compression ratio achieved is of 85.13%. Fig. 5.6 shows the reconstructed image after 1, 3, 5 and 7 iterations.

Fig 12.1 Original Image

Fig 12.2Reconstructed Image After 1 iteration

Fig 12.3 Reconstructed Image After 2 iteration

Fig 12.4 Reconstructed Image After 3 iteration

Fig 12.5 Reconstructed Image After 4 iteration

Fig12.2- 12-5 shows the reconstructed images after 1, 3,5 and 7 iteration using fractal image compression in wavelet domain.

Iteration No.	PSNR (dB)	Decoding Time (Seconds)
1	20.0523	1.8440
2	23.7026	3.3440
3	27.9967	4.7030
4	30.6742	6.0470
5	31.3298	7.4060
6	31.3298	8.7340
7	31.3298	10.0940

Table 4 showing PSNR, Decoding Time for different Iterations for image of Mahi

VI. CONCLUSION

Compression of image is an important field in Digital signal processing. In this paper, comparison of various transforms based image compression method is described. On the basis of Experimental comparisons on various images, we conclude that (1) Haar Wavelet based compression algorithms are strongly recommended, because it has good PSNR value. (2) JPEG DCT based approach might use an adaptive quantization table, (3) Fractal approach should utilize its resolution-free decoding property for a low bit rate compression. It has good compression ratio. But disadvantage is that it has poor encoding time. (4) Daubchies based approach is also very useful. It has very good PSNR value and encoding time.

So to speed up the process & to improve the MSE, DWT based compression can be done. Among Haar&Daubechies, Daubechies shows better result.

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