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Comparative Analysis of DCT, DWT &LWT 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 and information of image. In this paper, we present the comparison of the performance of Discrete cosine transform, Discrete wavelet transform & Lifting wavelet transform 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), Signal to noise ratio SNR, Mean squared error (MSE), Energy Retained (ER) & Execution time etc.

Index Terms— DWT, DCT, LWT, 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 amounts 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. This is because the amount of space required to hold unadulterated images can be prohibitively large in terms of cost.

Fortunately, 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. Using JPEG compression, the creator can decide how much loss to introduce and make a trade-off between file size and image quality.

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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 & LWT 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 oscillating at different frequencies. DCTs are important to numerous applications in science and engineering, from lossy compression of images (where small high-frequency components can be discarded). In any transformed image [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.

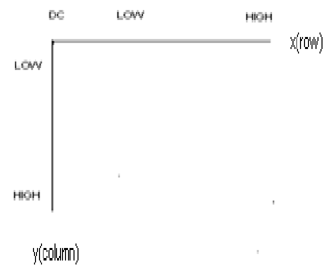

Figure 1:- Transformed image matrix, X columns denote horizontal spatial frequencies, Y columns denote vertical frequencies.

(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 not from $-\infty$ to $+\infty$ but only for finite time duration, as shown in Fig below. A wavelet as shown in figure 2(b) is a waveform of effectively limited duration that has an average value of zero.

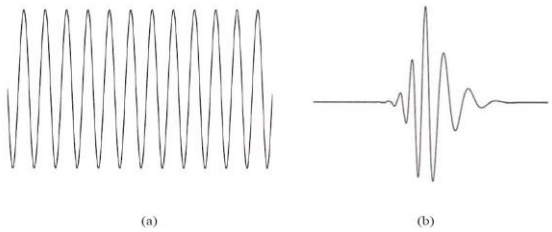

Figure2:- (a) A Wave (b) A Mother Wavelet

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 multi-resolution 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:

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

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

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 3.

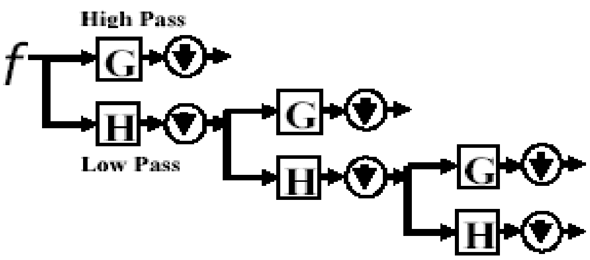

Figure 3:- Fiter iteration Series

(C) *Lifting Wavelet Transform:*

The lifting scheme (LS) [9] has been introduced for the efficient computation of DWT .For image compression, it is very necessary that the selection of transform should reduce the size of the resultant data as compared to the original data set .So a new lossless image compression method is proposed. Wavelet using the lifting scheme significantly reduces the computation time, speed up the computation process. The lifting transform even at its highest level is very simple.

The lifting transform can be performed via two operations: Split, Predict and Update.

Suppose we have the one dimensional signal a0. Lifting [9-11] is done by performing the following sequence of operations:

1. Split a0 into Even-1 and Odd-1
2. d-1 = Odd-1 – Predict (Even-1)
3. a-1 = Even-1 + Update(d-1)

These steps are repeated to construct multiple scales of the transform. The wire diagram in Figure 4 shows the forward transform visually. The coefficients “a” are representing the averages in the signal that is Approximation coefficient, while the coefficients in “d” represent the differences in the signal that is Detailed Coefficient. Thus, these two sets also correspond to the low- pass and high- pass frequencies present in the signal.

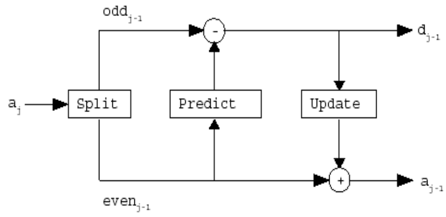

Figure4:- Wire diagram of forward transformation with the lifting scheme

The inverse transformation is also very simple as well. We only reverse the order of operations and change the signs. The even and odd sequences are then merged together to form the original signal. The wire diagram of inverse transformation is shown below in figure 5:

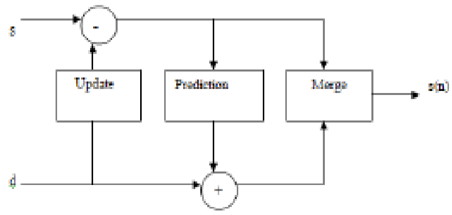

Figure5:- Wire diagram of Inverse Transformation with the lifting scheme

(D) *Properties OF Transforms:*

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

(i)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

(ii) 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 the quantizer to discard coefficients with relatively small amplitudes without introducing visual distortion in the reconstructed image.

(iii) Orthogonally: Basis functions of these transforms[12] are orthogonal . Thus, the inverse transformation matrix of A is equal to its transpose i.e. invA=AT

III. RESULTS AND DISCUSSION

The coding of this paper is done in MATLAB 7.In this paper, we compared Discrete cosine transform (DCT), Discrete wavelet transform (DWT) and the lifting transform (LWT). The quality of a compression method could be measured by the traditional distortion measures such as the peak signal to-noise ratio (PSNR), signal to noise ratio (SNR). Mean square error (MSE) & execution time (ET). We compared the performance of these transforms on image "Diwali (64 x 64)" . Fig.6 shows the reconstructed images of DCT, DWT & LWT.

Table 1 shows the SNR, PSNR, MSE & ET improvement for two images versus the original ones. The results of the experiment are as follows & the best results out of these are bolded.

Trans forms	Energy retainer	SNR(db)	Mean Square error	PSNR(db)	Execution time(sec)
DCT	99.9476	44.8230	46.7036	31.4373	9.6250
DWT	99.4026	56.1203	0.0019	75.3831	1.0938
LWT	**99.9498**	**73.9029**	**0.0008**	**79.3111**	**1.0625**

Table-1

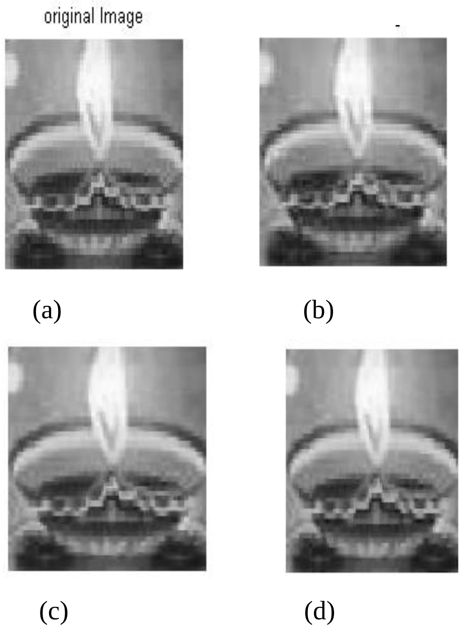

Fig 6(a) Original image ,6(b) Compressed by DCT,6(c) Compressed by DWT &6(d)Compressed by LWT

Figure 6:- Reconstructed Images

Here are the bar graphs plotted on the basis of results described in table 1. Figure 7 shows the improvement in PSNR(db) from DCT to DWT & then to LWT. From figure 10, it is clearly seen the improvement in the results of execution time (in seconds) from DCT to DWT & then to LWT.

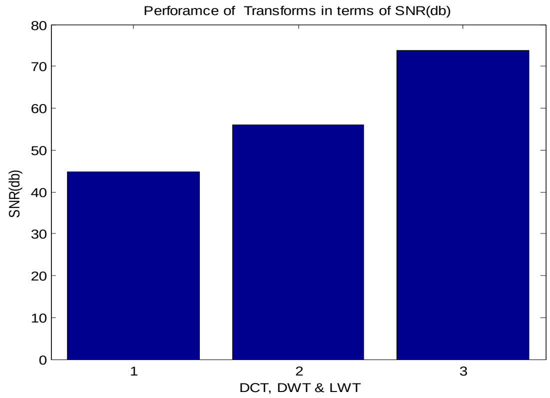

Figure 7:- Performance of Transforms in terms of SNR(db)

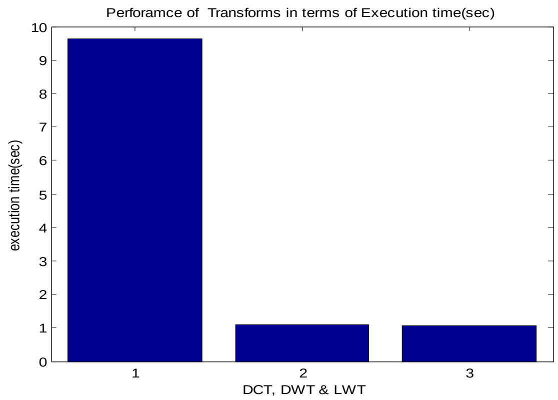

Figure 8:- Performance of Transforms in terms of Execution time(sec)

The two graphs shown below give the variation of PSNR & MSE with threshold value.The increase in threshold value means increasing the quantization levels.It can be clearly seen from figure 9 that for the same value of threshold mean square error(MSE) for LWT is quite less than DWT. Figure 10 concludes that with the increse in threshold value PSNR(db) decreses continously for DWT but it reamins always constant for LWT.

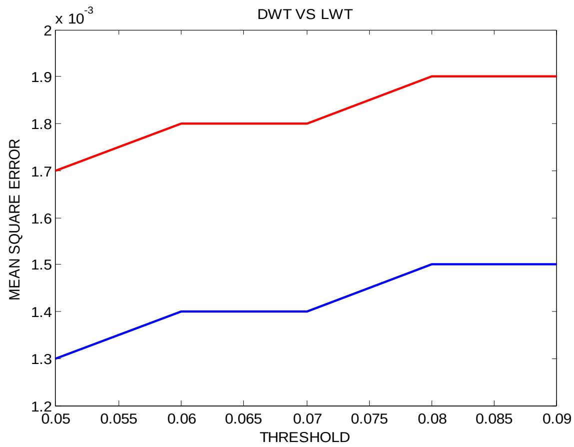

Figure 9:- Plot of MSE Vs threshold for DWT & LWT

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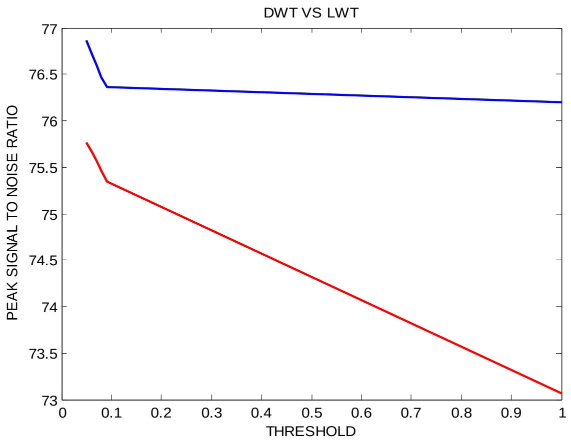

Figure 10:-Plot of PSNR(db) Vs threshold for DWT & LWT.
(RED LINE- DWT, BLUE LINE-LWT)

IV. CONCLUSION

Use Compression of image is an important field in Digital signal processing. In this paper, comparison of various transforms based image compression method is described. The DCT shows its best results in terms of energy compaction but execution time required & MSE that is the error between original & recovered image is not acceptable. So to speed up the process & to improve the MSE, DWT based compression can be done. But in DWT results SNR reduces so to improve further SNR & ET, lifting based decomposition process with a comparable performance in the compression ratio and peak signal to noise ratio (PSNR) and reconstructed image quality. Wavelet based compression is best suitable for the applications in which the speed is critical factor i.e. software based video conferencing and real time image compression systems. The speed up mechanism can be more improved by using the lifting scheme.

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