Image Compression using DCT, DWT and Hybrid Techniques

Manjot Kaur[1], Pawandeep Kaur[2]
[1]*M.Tech student, Guru Nanak Dev University, Amritsar*
[2]*Assistant Professor, Guru Nanak Dev University, Amritsar*

Abstract - Image compression means reducing the amount of data required to represent an image. Image compression is very important for efficient transmission and storage of images. Image compression is minimizing the size in bytes of a graphics file without degrading the quality of image to an unacceptable level. The main goal is to achieve higher compression ratios and minimum degradation in quality. The Discrete cosine transform (DCT) is a method for transforms a signal or image from spatial domain to frequency component. It is a widely used technique in image compression while DWT image compression includes decomposition (transform of image), detail coefficients thresholding, and entropy encoding. In this paper we are comparing DCT and DWT on the basis of performance parameters PSNR, MSE and CR.

Keywords - DCT (discrete cosine transform), DWT (discrete wavelet transform), MSE (mean square error), PSNR (peak signal to noise ratio)

I. INTRODUCTION

Image compression solves the issues of reducing the amount of data required to represent a digital image. It is a technology designed to yield a compact representation of an image, thereby reducing the image storage/transmission requirements. Compression is achieved by the removal of data redundancies. The main aim of image compression is to reduce the redundancy and irrelevancy present in the image, so that it can be stored and transferred efficiently. The compressed image is represented by less number of bits compared to original. Hence, the required storage size will be reduced, consequently maximum images can be stored and it can transferred in faster way to save the time, transmission bandwidth. For this purpose many compression techniques i.e. scalar/vector quantization, differential encoding, predictive image coding, transform coding have been introduced. Among all these, transform coding is most efficient especially at low bit rate.

In DCT image data are divided up into n*m number of block. DCT converts the spatial image representation into a frequency map: the average value in the block is represented by the low-order term, strength and more rapid changes across the width or height of the block represented by high order terms. DCT is simple when JPEG used, for higher compression ratio the noticeable blocking artifacts across the block boundaries cannot be neglected. The DCT is fast. It can be quickly calculated and is best for images with smooth edges. Discrete wavelet transform (DWT) has gained widespread acceptance in signal processing and image compression.

In lossless compression technique the reconstructed image after compression is identical to original image. Loss less compression technique is used only for a few applications with stringent requirement such as medical imaging. : Lossy compression technique is widely used because the quality of reconstructed images is adequate for most applications. In this technique the decompressed image is not identical to original image but reasonably closed to it. In general, lossy techniques provide for greater compression ratios than lossless techniques that are lossless compression gives good quality of compressed images but yields only less compression whereas the lossy compression techniques lead to loss of data with higher compression ratio. Transformation, quantization and encoding are the three basic steps involved in almost every still image compressing methods. Since, part of compression really happens during a step called quantization, where the less important frequencies are removed, it is called "lossy". Lossy compression technique is widely used because the quality of reconstructed images is adequate for most applications.

The Discrete wavelet transform (DWT) has achieved significant acceptance in image compression. The performance of discrete wavelet transforms based coding depends on the wavelet decomposition level and threshold value. The one-dimensional DCT is helpful in processing one-dimensional signals such as speech waveforms. We need a 2D version of the DCT data, for analysis of two-dimensional (2D) signals such as images, especially in coding for compression. JPEG is a commonly used standard method of compression for photographic images. The name JPEG stands for Joint Photographic Experts Group, the name of the committee who created the standard. JPEG provides for lossy compression of images. In this paper we made a comparative analysis of three transform coding techniques, viz. DCT, DWT and hybrid i.e. combination of both DCT and DWT based on different performance measure such as Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Compression Ratio (CR). This paper is divided as follows :Section 2 explains Discrete Cosine Transform (DCT) algorithm; Section 3 describes the Discrete Wavelet Transform (DWT) algorithm; section 4 explains combination of both DCT and DWT algorithm ; Section 5 included comparative analysis and result in tabular form and in last Section gives the conclusions.

II. DISCRETE COSINE TRANSFORM (DCT)

Discrete cosine transform (DCT) is the basis of many image compression methods. Discrete Cosine Transform (DCT) exploits cosine functions, it transform a signal from spatial representation into frequency domain. The DCT represents an image as a sum of sinusoids of varying magnitudes and frequencies. DCT is an orthogonal transform, the Discrete Cosine Transform (DCT) attempts to decorrelate the image data. After decorrelation each transform coefficient can be encoded independently without losing compression efficiency.

After the computation of DCT coefficients, they are normalized according to a quantization table with different scales provided by the JPEG standard computed by psycho visual evidence. Selection of quantization table affects the entropy and compression ratio. In a lossy compression technique, during a step called Quantization, the less important frequencies are discarded, and then the most important frequencies that remain are used to retrieve the image in decomposition process.DCT involves following steps:

1. The image is divided into 8*8 blocks.
2. The two dimensional DCT is computed for each block.
3. The DCT blocks are then quantised and encoded.
4. Inverse DCT is computed and image is reconstructed.

An image is represented as a two dimensional matrix, 2-D DCT is used to compute the DCT Coefficients of an image. The 2-D DCT for an NXN input sequence can be defined as follows:

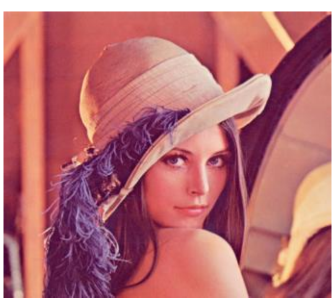

Fig.1. Original image (48 kb)

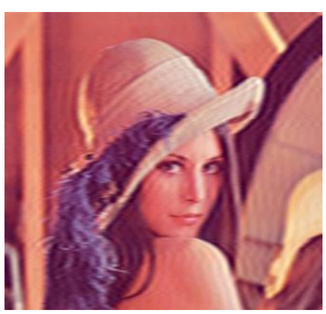

Fig.2.DCT compressed image (27.4 kb)

Blocking artefacts is a distortion that appears due to heavy compression and appears as abnormally large pixel blocks. The example of appearance of blocking artefact due to high compression is shown in Fig.2.

III. DISCRETE WAVELET TRANSFORM (DWT)

Wavelets are mathematical functions that are local in time and scale and generally have an irregular shape which cut up data into different frequency components. A wavelet is a waveform of effectively limited duration that has an average value of zero. The most important feature of wavelet transform is it allows multiresolution decomposition. An image that is decomposed by wavelet transform can be reconstructed with desired resolution. The DWT represents an image as a sum of wavelet functions, known as wavelets, with different location and scale. It represents the data into a set of high pass (detail) and low pass (approximate) coefficients. The input data is passed through set of low pass and high pass filters. First of all, the low pass filter is applied for each row of data, and then we obtain low frequency components of the row. As the LPF is a half band filter, the output data consists of frequencies only in the first half of the original frequency range. By Shannon's Sampling Theorem, they can be sub sampled by two, so that the output data contains only half the original number of samples, similarly the high pass filter is applied for the same row of data, and now the high pass components are separated, and placed by the side of the low pass components. This procedure is done for all rows.

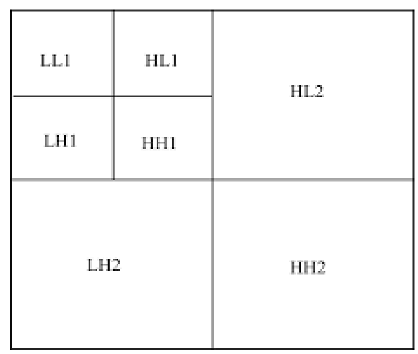

Fig.3: Two level decomposition using DWT

The steps of the algorithm are described below as under:
1. Choose a wavelet; choose decomposition level N. Compute the wavelet.
2. For each level from 1 to N, a threshold is selected and Hard/soft thresholding is applied to the detail coefficients.
3. Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

IV. HYBRID IMAGE COMPRESSIONS

The following hybrid DWT-DCT algorithm for image compression makes use of the properties of both the DWT and the DCT. Take an image of square dimensions. Decompose the image into 2 levels. Apply 2-D DWT true compression on it. The synthesised image is further decomposed using another 2-D DWT level 2 and the higher coefficients (HL, LH and HH) are discarded. DCT is applied to the reaming approximate DWT coefficients (LL) and can be achieved high CR.

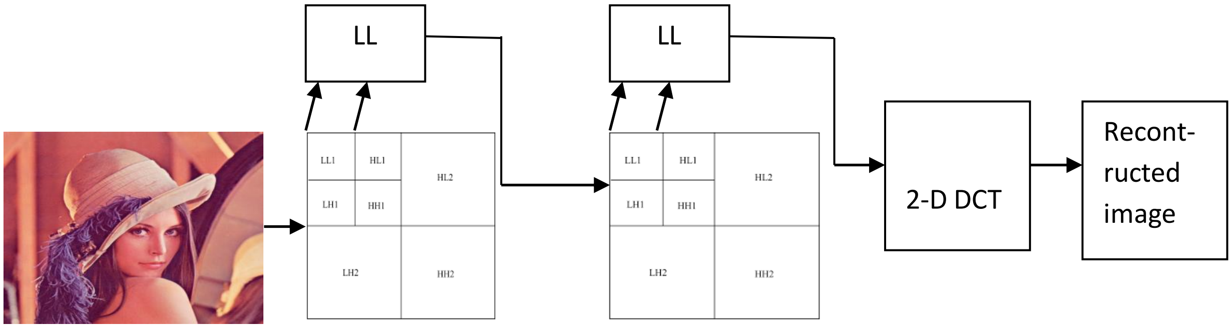

Fig.4: Hybrid (DCT-DWT) image compression

V. LITERATURE SURVEY

Anil Kumar et al. in their paper two image compression techniques namely, DCT and DWT are simulated. They concluded that DWT technique is much efficient than DCT in quality and efficiency wise but in performance time wise DCT is better than DWT [7]. Aree Ali Mohammed and Jamal Ali Hussein (2011) presented a scheme for medical image compression based on hybrid compression technique (DWT and DCT) to achieve higher compression rates [8]. Amanjot kaur compared the results of different transform coding techniques i.e. Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) we see that DWT provides higher compression ratios & avoids blocking artifacts, allows good localization both in spatial & frequency domain. Transformation of the whole image introduces inherent scaling. Better identification of which data is relevant to human perception higher compression ratio and we also see that DCT takes more time than DWT [9]. Sriram and Thiyagarajan (2012) proposed a hybrid DWT-DCT technique which performed better than standalone DWT and DCT [10]. Ramandeep Kaur Grewal and Navneet Randhawa (2012) developed a robust DWT-DCT algorithm for image compression and reconstruction. It involves the following steps: Acquired image is divided into NxN blocks and 2D DWT is applied to decompose the image; the low frequency coefficients are passed to the next stage and decomposed while the high frequency coefficients are discarded [11].

VI. PERFORMANCE PARAMETERS

Analysis was done on the basis of the amount of distortion, which was calculated using important distortion measures: mean square error (MSE), peak signal-to-noise ratio (PSNR) measured in decibels (dB) and compression ratio (CR) measures were used as performance indicators.

1. Mean Square Error (MSE): The MSE is the cumulative squared error between the compressed and the original image. A lower value of MSE means lesser error, and it has the inverse relation with PSNR.

$$\text{MSE} = \frac{1}{m*n}\sum_{y=1}^{m}\sum_{x=1}^{n}[I(x,y) - I'(x,y)]^2$$

Where, I(x, y) is the original image and I'(x, y) is the reconstructed image and m, n are the dimensions of the image. Lower the value of MSE, the lower the error and better picture quality.

2. Peak Signal to Noise ratio (PSNR): It is the ratio between the maximum possible power of a signal and the power of the corrupting noise.

$$\text{PSNR} = 20 * \log_{10}\left(\frac{max_I}{\sqrt{MSE}}\right)$$

3. Compression ratio (CR): Compression ratio is described as:

$$\text{CR} = \frac{Size\ of\ original\ image}{Size\ of\ compressed\ image}$$

VII. RESULTS AND COMPARISONS

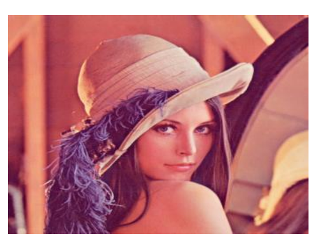

Fig.5. lena original (48 kb)

Fig.6. peppers original (42 kb)

Fig.7. Opera house original (48kb)

Fig.8. Taj mahal original(192 kb)

Table 1. Comparison of various methods using performance parameters

	PSNR	MSE	CR
(LENA) DCT	40.9877	5.2205	1.103
DWT	41.16	4.984	1.340
HYBRID	34.74	21.985	1.558
DWT threshold=20	37.4879	11.804	1.51
(PEPPERS) DCT	39.03	8.231	0.875
DWT	41.4	4.715	1.055
HYBRID	34.5159	23.167	1.308
DWT threshold=20	38.979	8.2965	1.24
(OPERA) DCT	41.57	4.582	1.6
DWT	38.31	9.6996	1.64
HYBRID	34.40	23.8006	2.15
DWT threshold=20	37.71	11.119	1.78
(TAJMAHAL) DCT	36.91	13.37	5.81
DWT	41.02	5.147	5.61
HYBRID	34.0016	26.09	7.30
DWT threshold=20	36.341	15.24	6.17

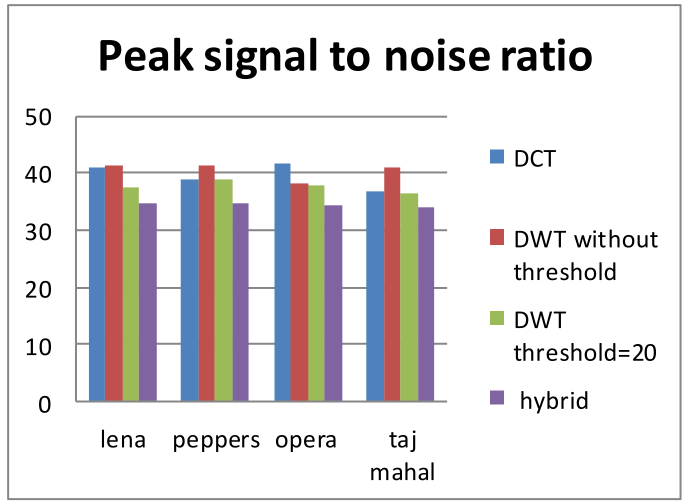

Fig.9: PSNR using various techniques

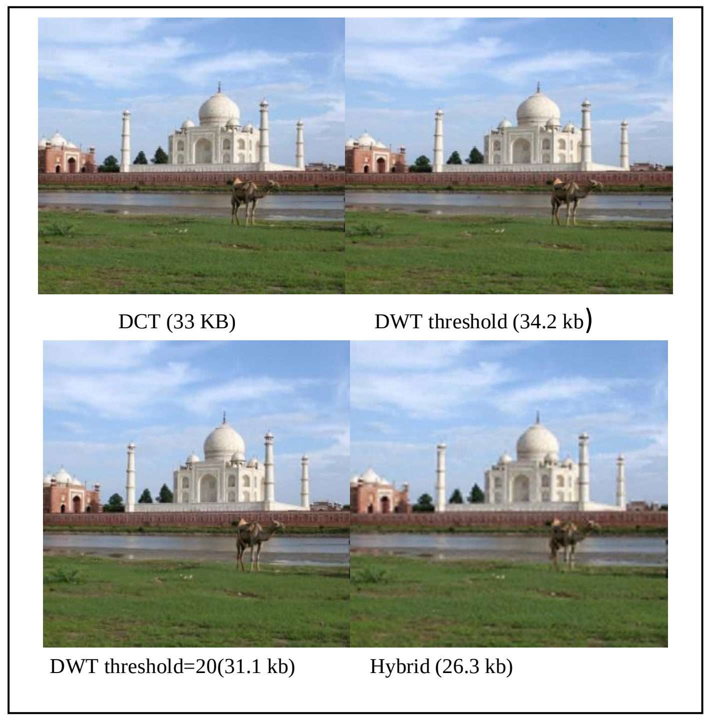

Fig.10: Reconstructed images using various techniques

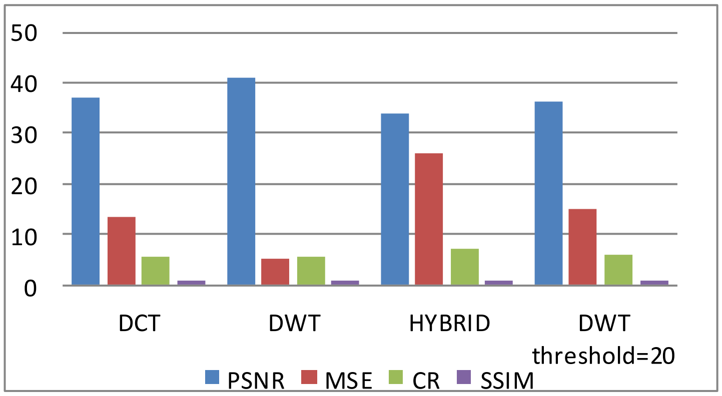

Fig.11: Image of Taj Mahal compared compared using various parameters

Table.2 Structural Similarity Index (SSIM) for measuring image quality for all images

IMAGES	DCT	DWT	DWT THRESHOLD	HYBRID
Lena	0.9887	0.9942	0.9888	0.9647
peppers	0.9926	0.9984	0.9925	0.9572
opera	0.9670	0.9737	0.9618	0.8825
Taj mahal	0.9624	0.9713	0.9559	0.8836

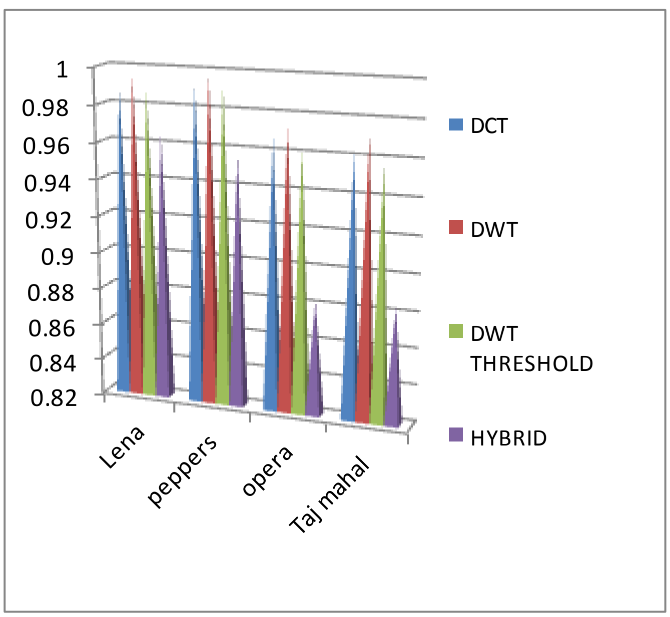

Fig.12: SSIM comparison

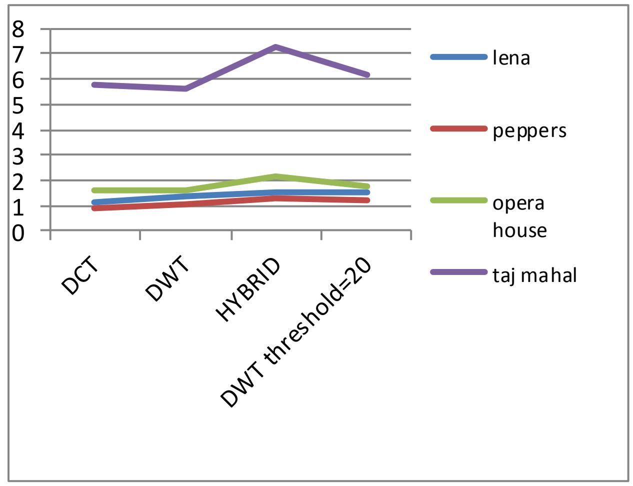

Fig.13: Compression ratio with various techniques

VIII. CONCLUSION

In our paper, the colour images were compressed effectively using DCT, DWT and hybrid techniques. The highest compression ratio is achieved using hybrid technique. But if we look at the image quality it is best by using true compression 2-D DWT without threshold. Generally, the DCT based compression technique produce some blocking artifacts. Wavelets are better suited to image compression and wavelet based compression technique maintains better image quality by reducing errors.

IX. FUTURE SCOPE

Now a day's many compression techniques are evolving hence the selection of high PSNR value will lead to maintain the quality of an image and achievement is in compression process. This work can be expanded by applying new encoding techniques to get better PSNR at high CR.

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