A Comparative Study of DCT, DWT & Hybrid (DCT-DWT) Transform

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Abstract : Image compression is process to remove the redundant information from the image so that only essential information can be stored to reduce the storage size, transmission bandwidth and transmission time. The essential information is extracted by various transforms techniques such that it can be reconstructed without losing quality and information of the image. In this paper comparative analysis of image compression is done by three transform method, which are Discrete Cosine Transform (DCT),Discrete Wavelet Transform (DWT) & Hybrid (DCT+DWT) Transform. Matlab programs were written for each of the above method and concluded based on the results obtained that hybrid DWT-DCT algorithm performs much better than the standalone JPEG-based DCT, DWT algorithms in terms of peak signal to noise ratio (*PSNR*), as well as visual perception at higher compression ratio.

Keywords- Image compression, DCT, DWT, HYBRID (DCT+DWT).

Introduction: The main purpose 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. In image compression methodology, generally spectral and spatial redundancy should be reduced as much as possible. There are many applications where the image compression is used to effectively increased efficiency and performance. Applications are like Health Industries, Retail Stores, Security Industries, Museums and Galleries etc.

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 [1]. Transform coding relies on the principle that pixels in an image show a certain level of correlation with their neighbouring pixels. Consequently, these correlations can be exploited to predict the value of a pixel from its respective neighbours. A transformation is, therefore, defined to map this spatial (correlated) data into transformed (uncorrelated) coefficients. Clearly, the transformation should utilize the fact that the information content of an individual pixel is relatively small i.e., to a large extent visual contribution of a pixel can be predicted using its neighbours. Depending on the compression techniques the image can be reconstructed with and without perceptual loss. In lossless compression, the reconstructed image after compression is numerically identical to the original image. In lossy compression scheme, the reconstructed image contains degradation relative to the original. Lossy technique causes image quality degradation in each compression or decompression step. In general, lossy techniques provide for greater compression ratios than lossless techniques i.e. Lossless compression gives good quality of compressed images, but yields only less compression whereas the lossy compression techniques [2] lead to loss of data with higher compression ratio .The approaches for lossy compression include lossy predictive coding and transform coding. Transform coding, which applies a Fourier-related transform such as DCT and Wavelet Transform such as DWT are the most commonly used approach [3]. 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), Compression Ratio (CR), computational complexity.

This paper is divided as follows :Section 2 explains Discrete Cosine Transform (DCT) algorithm; Section 3 describes the Discrete Wavelet Transform (DWT) algorithm ; combination of both DCT and DWT algorithm explained in Section 4 ; Section 5 included comparative analysis and result in tabular form and in last Section gives the conclusions.

2 DISCRETE COSINE TRANSFORM (DCT)

Typical image compression block is shown in fig.1, which explains flow of process involved in image compression. 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.

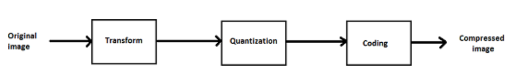

Fig.1 Image compression model

DCT has the property that, for a typical image most of the visually significant information about an image is concentrated in just few coefficients of DCT. 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. The value of quantization is inversely proportional to quality of reconstructed image, better mean square error and better compression ratio. In a lossy compression technique, during a step called Quantization, the less important frequencies are discarded, Then the most important frequencies that remain are used to retrieve the image in decomposition process. [4]. After quantization, quantized coefficients are rearranged in a zigzag order for further compressed by an efficient lossy coding algorithm . DCT has many advantages:

(1) It has the ability to pack most information in fewest coefficients.

(2) It minimizes the block like appearance called blocking artifact that results when boundaries between sub-images become visible [4].

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 [5]:

$$D(i,j) = \frac{1}{\sqrt{2N}} C(i)C(j) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} P(x,y) \times \cos\left(\frac{(2x+1)i\pi}{2N}\right) \cos\left(\frac{(2y+1)j\pi}{2N}\right) \quad (1)$$

Where,

P(x, y) is an input matrix image NxN, (x, y) are the coordinate of matrix elements and (i, j) are the coordinate of coefficients, and

$$C(u) = \begin{Bmatrix} \frac{1}{\sqrt{2}} & if\ u = 0 \\ 1 & if\ u > 0 \end{Bmatrix} \quad (2)$$

The reconstructed image is computed by using the inverse DCT (IDCT) according to

$$P(x,y) = \frac{1}{\sqrt{2N}} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} C(i)C(j)D(i,j) \times \cos\left(\frac{(2x+1)i\pi}{2N}\right) \cos\left(\frac{(2y+1)j\pi}{2N}\right) \quad (3)$$

The pixels of black and white image are ranged from 0 to255, where 0 corresponds to a pure black and 255 corresponds to a pure white. As DCT is designed to work on pixel values ranging from -128 to 127, the original block is levelled off by 128 from every entry. Step by step procedure of getting compressed image using DCT and getting reconstructed image from compressed image can be illustrated through flow charts as shown in fig.2 and fig 3.

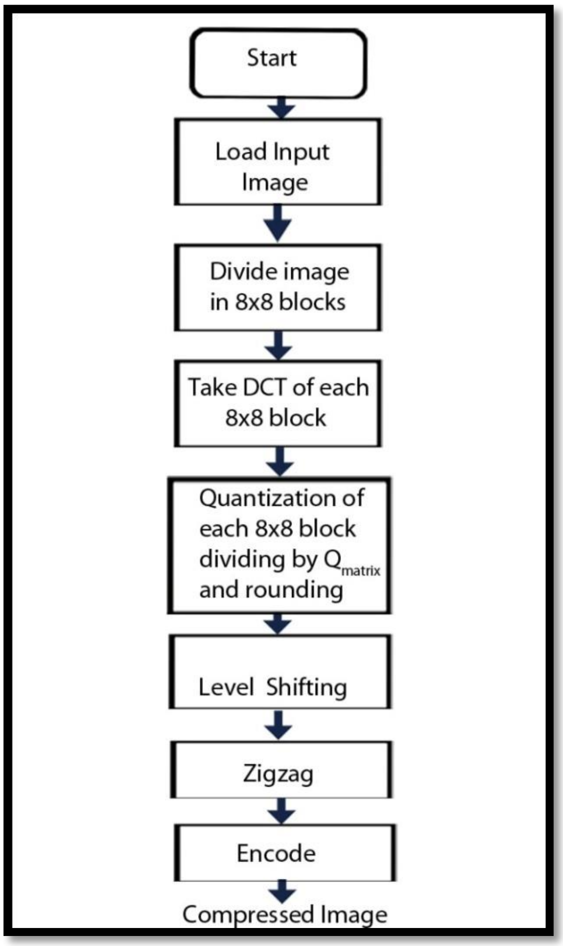

Fig. 2 Flow chart of compression technique

2.1 Coding scheme

2.1.1 Compression procedure

First the whole image is loaded to the encoder side, then we do RGB to GRAY conversion after that whole image is divided into small NXN blocks (here N corresponds to 8) then working from left to right, top to bottom the DCT is applied to each block. Each block's elements are compressed through Quantization means dividing by some specific 8X8 matrix called $Q_{matrix}$and rounding to the nearest integer value.This Q_{matrix} is decided by the user to keep in mind that it gives Quality levels ranging from 1 to 100, where 1 gives the poor image Quality and highest compression ratio while 100 gives best Quality of decompressed image and lowest compression ratio.

We choose Q_{matrix}, with a Quality level of 50, $Q_{50matrix}$ gives both high compression and excellent decompressed image. By using Q_{10} we get significantly more number of 0's as compared to Q_{90} . After Quantization, all of the quantized coefficients are ordered into the "zigzag" sequence. Now encoding is done and transmitted to the receiver side in the form of one dimensional array. This transmitted sequence saves in the text format.
The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space.

2.1.2 Decompression procedure

To reconstruct the image, receiver decodes the quantized DCT coefficients and computes the inverse two dimensional DCT (IDCT) of each block, then puts the blocks back together into a single image in same manner as we done in previously. The dequantization is achieved by multiplying

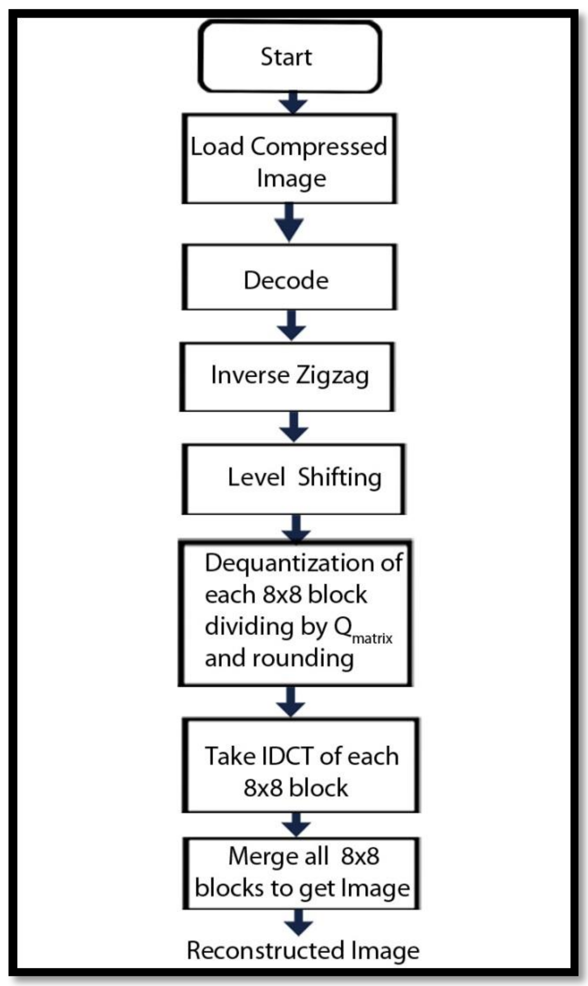

Fig. 3 Flow chart of decompression technique

each element of the received data by corresponding element in the quantization matrixQ_{matrix}, then we add 128 to each element for getting level shift. In this decoding process, we have to keep block size (8X8) value same as it used in encoding process. These blocks are merged and arranged in same order in which they were decomposed for compression to get the decompressed image. The following flow chart explains whole decompression procedure step by step.

3 DISCRETE WAVELET TRANSFORM (DWT)

Wavelets are useful for compressing signals. They can be used to process and improve signals, in fields such as medical imaging where image degradation is not tolerated. Wavelets can be used to remove noise in an image. Wavelets are mathematical functions that can be used to transform one function representation into another. Wavelet transform performs multiresolution image analysis. Multiresolution means simultaneous representation of image on different resolution levels. Wavelet transform represent an image as a sum of wavelets functions, with different location and scales. The 2D wavelet analysis uses the same 'mother wavelets' but requires an extra step at every level of decomposition.

In 2D, the images are considered to be matrices with N rows and M columns. Any decomposition of an image into wavelets involves a pair of waveforms-

- One to represent the high frequency corresponding to the detailed part of the image (wavelet function)
- One for low frequency or smooth parts of an image (scaling function).

At every level of decomposition the horizontal data is filtered, then the approximation and details produced from this are filtered on columns. At every level, four sub-images are obtained; the approximation, the vertical detail, the horizontal detail and the diagonal detail. Wavelet function for 2-D DWT can be obtained by multiplying wavelet functions ($\Psi(x,y)$) and scaling function ($\varphi(x,y)$). After first level decomposition we get four details of image those are,

Approximate details – $\Psi(x,y)= \varphi(x)\ \varphi(y)$
Horizontal details – $\Psi(x,y)= \varphi(x)\Psi(y)$
Vertical details – $\Psi(x,y)= \Psi(x)\varphi(y)$
Diagonal details – $\Psi(x,y)= \Psi(x)\Psi(y)$

The approximation details can then be put through a filter bank, and this is repeated until the required level of decomposition has been reached. The filtering step is followed by a sub-sampling operation that decreases the resolution from one transformation level to the other. After applying the 2-D filler bank at a given level n, the detail coefficients are output, while the whole filter bank is applied again upon the approximation image until the desired maximum resolution is achieved. Fig.1 shows wavelet filter decomposition. The sub-bands are labelled by using the following notations [6],

- **LLn**represents the approximation image n^{th} level of decomposition, resulting from low-pass filtering in the vertical and horizontal both directions.
- **LHn**represents the horizontal details at n^{th} level of decomposition and obtained from horizontal low-pass filtering and vertical high-pass filtering.
- **HLn**represents the extracted vertical details/edges , at n^{th} level of decomposition and obtained from vertical low-pass filtering and horizontal high-pass filtering.
- **HHn**represents the diagonal details at n^{th} level of decomposition and obtained from high-pass filtering in both directions.

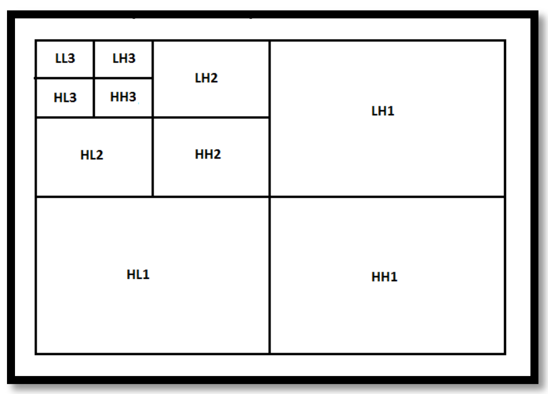

Fig.4 Wavelet Filter Decomposition

3.1 Coding scheme

3.1.1 Compression procedure

Original image is passed through HPF and LPF by applying filter first on each row. Output of the both image resulting from LPF and HPF is considered as L1 and H1 and they are combine into A1, where A1=[L1,H1]. Then A1 is down sampled by 2. Again A1 is passed through HPF and LPF by applying filter now on each column. Output of the above step is suppose to L2 and H2 and they are combined to get A2, where A2=$\begin{bmatrix} L2 \\ H2 \end{bmatrix}$. Now , A2 is down sampled by 2 to get compressed image. We get this compressed image by using one level of decomposition, to get more compressed image i.e. to get more compression ratio we need to follow above steps more number of times depending on number of decomposition level required. First level of decomposition gives four detailed version of an image those are shown in fig.3

3.1.2 Decompression procedure

Extract LPF and HPF images from compressed image by simply taking upper half rectangle of matrix is LPF image and down half rectangle is HPF image. Then both images are up sampled by2. Now take the summation of both images into one image called B1.Then again extract LPF image and HPF image by dividing vertically. Two halves obtained are filtered through LPF and HPF, summation of these halves gives the reconstructed image

4 HYBRID (DCT + DWT) TRANSFORM

The aim of image compression is to reduce the storage size with high compression and less loss of information. In section II and III we presented two different ways of achieving the goals of image compression, which have some advantages and disadvantages, in this section we are proposing a transform technique that will exploit advantages of DCT and DWT, to get compressed image. Hybrid DCT-DWT transformation gives more compression ratio compared to JPEG and JPEG2000, preserving most of the image information and create good quality of reconstructed image. Hybrid (DCT+DWT) Transform reduces blocking artefacts, false contouring and ringing effect [8].

4.1 Coding scheme

4.1.1 Compression procedure

The input image is first converted to gray image from colour image, after this whole image is divided into size of 32x32 pixels blocks. Then 2D-DWT applied on each block of 32x32 block, by applying 2 D-DWT, four details are produced. Out of four sub band details, approximation detail/sub band is further transformed again by 2 D-DWT which gives another four sub-band of 16x16 blocks. Above step is followed to decompose the 16x16 block of approximated detail to get new set of four sub band/ details of size 8x8. The level of decomposition is depend on size processing block obtained initially, i.e. here we are dividing image initially into size of 32x32, hence the level of decomposition is 2. After getting four blocks of size 8x8, we use the approximated details for computation of discrete cosine transform coefficients. These coefficients are then quantize and send for coding.

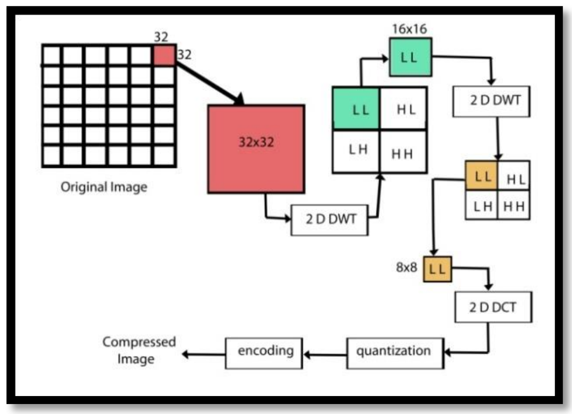

Fig.5 Compression technique using Hybrid transform

4.1.2 Decompression procedure

At receiver side, we decode the quantized DCT coefficients and compute the inverse two dimensional DCT (IDCT) of each block. Then block is dequantized. Further we take inverse wavelet transform of the dequantized block. Since the level of decomposition while compressing was two, we take inverse wavelet transform two times to get the same block size i.e. 32x32. This procedure followed for each block received. When all received blocks are converted to 32x32 by following decompression procedure, explained above. We arrange all blocks to get reconstructed image. The complete coding and decoding procedure is explained in fig. 5 and fig.6 respectively.

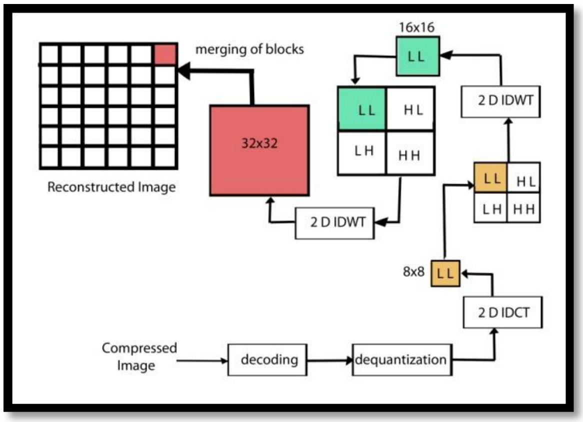

Fig.6 Decompression technique using Hybrid transform

5 COMPARATIVE ANALYSIS AND RESULTS

For comparative analysis codes for DCT, DWT and Hybrid techniques were written in MATLAB and results are tabulated in table 1. The results are obtained for images of sizes 128x128 and 512x512. Original and reconstructed images are also shown in fig 4. It can seen from table 1, the compression ratio CR is high for Hybrid transform as compare to standalone transforms. DWT comprises between compression ratio and quality of reconstructed image, it adds speckle noise to the image for improvement in the reconstructed image. Hence DWT technique is useful in medical applications. DCT gives less compression ratio but it is computationally efficient compared to other techniques.

6 CONCLUSION

In this paper comparative analysis of various Image compression techniques for different images is done based on three parameters compression ratio(CR), mean square error (MSE), peak signal to noise ratio (PSNR). Our results shows that we can achieve higher compression ratio using Hybrid technique but loss of information is more. DWT gives better compression ratio without losing more information of image. Pitfall of DWT is, it requires more processing power. DCT overcomes this disadvantage since it needs less processing power, but it gives less compression ratio. DCT based standard JPEG uses blocks of image,but there is still correlation exits across blocks. Block boundaries are noticeable in some cases. Blocking artifacts can be seen at low bit rates. In wavelet, there is no need to block the image. More robust under transmission errors . It facilitates progressive transmission of the image (scalability). Hybrid transform gives higher compression ratio but for getting that clarity of the image is partially trade off. It is more suitable for regular applications as it is having a good compression ratio along with preserving most of the information.

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Image	Image Size	Technique used	Compression Ratio	MSE	PSNR
Image 1 (jas.jpg)	128x128	DCT	2.6122	4.342	49.4436
		DWT	3.2365	4.165	50.3181
		Hybrid	10.2989	44.148	31.6817
	512x512	DCT	26.5462	0.9732	48.2488
		DWT	30.237	6.1613	40.2341
		Hybrid	52.539	113.2097	27.5920
Image 2 (lena.jpg)	128x128	DCT	2.3690	0.0676	59.8335
		DWT	2.9231	1.9067	45.3279
		Hybrid	9.6481	35.0658	32.6820
	512x512	DCT	24.5156	2.8152	43.6357
		DWT	29.8172	29.3150	33.4599
		Hybrid	49.7381	122.4307	27.2519

Table 1. Comparative analysis

Fig. 7 Comparison of visual image quality of reconstructed image for DCT, DWT AND HYBRID (DCT+DWT) for test images.

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