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 a comparative study of image compression is done by three transform methods, which are Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) & Hybrid (DCT+DWT) Transform. A study is based on previous paper result showing 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)

1. 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 neighbors. 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 neighbors. 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 study of the 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 gives the conclusions.

2. DISCRETE COSINE TRANSFORM (DCT)

Several techniques can transform an image into frequency domain, such as DCT, DFT [1] and wavelet transform. Each transform has its advantages. First here the DCT technique is discussed. The most common DCT definition of a 1-D sequence of length N is:

$$Y[k] = C[k] \sum_{n=0}^{N-1} X[n] \cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad \textbf{(1)}$$

For k= 0,1,2,…,$N-$ 1. Similarly, the inverse DCT transformation is defined as

$$X[n] = \sum_{k=0}^{N-1} C[k] Y[k] \cos\left[\frac{(2n+1)k\pi}{2N}\right] \quad \textbf{(2)}$$

For k= 0,1,2,…,$N-$ 1 . In both equations (1.1) and (1.2) C[n] is defined as

$$C[n] = \begin{bmatrix} \sqrt{\frac{1}{N}} & for\ n = 0 \\ \sqrt{\frac{2}{N}} & for\ n = 1,2,\dots,N-1 \end{bmatrix} \quad \textbf{(3)}$$

The 2-D DCT is a direct extension of the 1-D case and is given by

$$y[j,k] = C[j]C[k] \sum_{m=0}^{N-1} \sum_{n=1}^{N-1} x[m,n] \cos\frac{2m+1}{2N} \cos\frac{(2n+1)k\pi}{2N} \quad \textbf{(4)}$$

Where: m, n = 0, 1, 2,… N −1. And c[n] is as it is as in 1-D transformation.

Discrete cosine transform (DCT) is widely used in image processing, especially for compression algorithm for encoding and decoding in DCT technique is shown below.

2.1. Encoding System

There are four steps in DCT technique to encode or compress the image.

Step1. The image is broken into N*N blocks of pixels. Here N may be 4, 8, 16,etc.

Step2. Working from left to right, top to bottom, the DCT is applied to each block.

Step3. Each block's elements are compressed through quantization means dividing by some specific value.

Step4. The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space.

So first the whole image is divided into small N*N blocks then DCT is applied on these blocks. After that for reducing the storage space DCT coefficients [5] are quantized through dividing by some value or by quantization matrix. So that large value is become small and it need small size of space. This step is a lossy step. So selection of quantization value or quantization matrix is affect the entropy and compression ratio. If we take small value for quantization then we get the better quality or less MSE (Mean Square Error) but less compression ratio. Block size value also affects quality and compression ratio. Simply the higher the block size higher the compression ratio but with loss of more information and quality.

2.2. Decoding System

Decoding system is the exact reverse process of encoding. There are four steps for getting the original image not exact but identical to original from compressed image.

Step1. Load compressed image from disk.

Step2. Image is broken into N*N blocks of pixels.

Step3. Each block is de-quantized by applying reverse process of quantization.

Step4. Now apply inverse DCT on each block. And combine these blocks into an image which is identical to the original image.

In this decoding process, we have to keep N's value same as it used in encoding process. Then we do de-quantization process by multiplying with quantization value or quantization matrix. As earlier said that this is lossy technique so output image is not exact copy of original image but it is same as original image. So this process' efficiency is measure by compression ratio. Compression ratio [3] is defined by ratio of storage bits of original image and storage bits of compressed image.

$$Cr = \frac{n1}{n2} \quad \textbf{(4)}$$

Where n1 is number of bits to store original image and n2 is number of bits to store compressed image.

Loss of information is measure by Mean square Error (MSE)[1,5] between reconstructed image and original image. If MSE of reconstructed image to original image is greater than the information lost is more.

$$MSE = \sum_{i=1}^{M}\sum_{j=1}^{N}\left(x(i,j) - x'(i,j)\right)^2 \quad \textbf{(5)}$$

Where M,N is dimension of image. x(i, j) is pixel value of (i,j) coordinate of original image while

x'(i,j) is the reconstructed image's pixel value.

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 a 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, and 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 (ψ (x,y)) and scaling function (φ(x,y)).

After first level decomposition we get four details of image those are,

Approximate details –ψ (x, y) = φ(x) φ(y)

Horizontal details –ψ (x, y) = φ(x) ψ (y)

Vertical details – ψ (x, y) = ψ (x) φ(y)

Diagonal details – ψ (x, y) = ψ (x) ψ (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. 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.

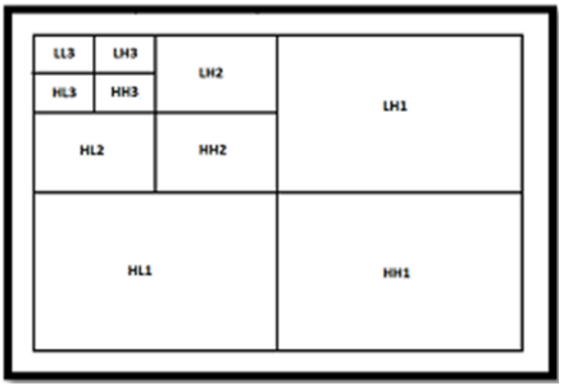

Figure 3.1: Wavelet filter Decomposition

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

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.

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 blocks, 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.

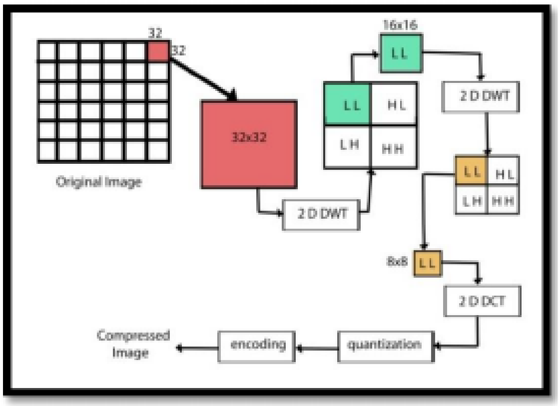

Fig.: 4.1: Compression technique using Hybrid transform

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. 4.1 and fig.4.2 respectively.

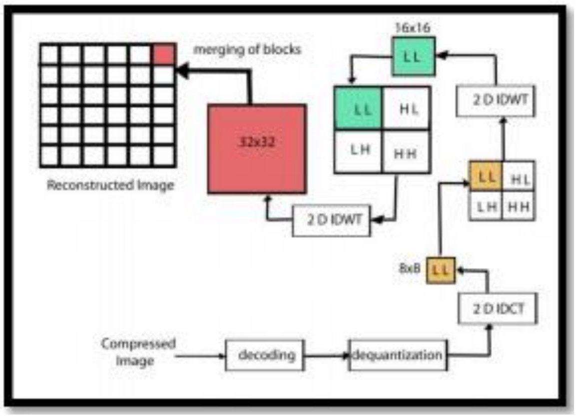

Fig.: 4.2: Decompression technique using Hybrid transform

5. CONCLUSION

In this paper comparative study 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 are 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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