A Comparative Study of Image Compression Techniques

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***Abstract*—The spread of computing has led to the need for storage and transmission of massive volume of image data. This growth has led to a need for Image data compression. Transformation codings are considered to be standard techniques for image data compression. Many studies related to use of these techniques in image compression have been reported in literature. Among these Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) based image codec's are used widely due to their improved performance and efficiency. In comparison to DWT, DCT has some short comings such as i) it lacks multi-resolution property, ii) offers less compression ratio, iii) fixed functions, and iv) blocking artifacts. DWT has overcome these problems and also offers a number of properties such as region of interest, better energy compaction, and adaptive spatial-frequency resolution, allows good localization both in time and spatial frequency domain. In this paper, major lossy and lossless compression techniques have been studied and compared in terms of Mean square error (MSE), Peak signal to noise ratio (PSNR), and Compression Ratio (C_r).**

Keywords— Discrete Cosine Transform; Discrete Wavelet Transform; Mean square error; Peak signal to noise ratio; Compression Ratio.

I. INTRODUCTION

The probabilistic view of information, its representation, transmission, and compression was formulated in 1941 by Shannon et al [1]. Initially, emphasis of research in image compression was on the development of analog methods for reducing video transmission bandwidth, however, with the advent of digital computers and subsequent development of advanced integrated circuits, attention shifted from analog compression to digital approaches. With the development of practical application based on several key international image compression standards, the field has experienced substantial growth. The main purpose of image compression is to store or transmit images in an efficient form. Compression is achieved by lessening redundancies such as inter-pixel redundancy, psycho-visual redundancy, and coding redundancy of the image data.

A. Inter-Pixel Redundancy

In image neighbouring pixels are not statistically independent. It is due to the correlation between the neighboring pixels of an image. This type of redundancy is called Inter-pixel redundancy. This type of redundancy is sometime also called spatial redundancy. This redundancy can be explored in several ways, one of which is by predicting a pixel value based on the values of its neighboring pixels. In order to do so, the original 2-D array of pixels is usually mapped into a different format, e.g., an array of differences between adjacent pixels. If the original image pixels can be reconstructed from the transformed data set the mapping is said to be reversible.

B. Psycho Visual Redundancy

Many experiments on the psycho physical aspects of human vision have proven that the human eye does not respond with equal sensitivity to all incoming visual information; some pieces of information are more important than others. Most of the image coding algorithms in use today exploit this type of redundancy, such as the Discrete Cosine Transform (DCT) based algorithm at the heart of the JPEG encoding standard.

C. Coding Redundancy

Consists in using variable length code words selected as to match the statistics of the original source, in this case, the image itself or a processed version of its pixel values. This type of coding is always reversible and usually implemented using lookup tables (LUTs). Examples of image coding schemes that explore coding redundancy are the Huffman codes and the arithmetic coding technique.

Through this process, image represented as a 2-D pixel array is transformed into a statistically unrelated data set. This transformation is applied to the image before its storage or transmission so that storage space and transmission time is saved. Later on, original image or its approximation is reconstructed from the compressed image, which the human eye is capable to tolerate. The speed of compression and decompression of an image depends on various factors that include compression method employed, system hardware, and type of the file.

Due to the dynamic role of image compression in diverse application, it has been recognized as an "Enabling technology". These include facsimile transmission (FAX), medical imaging [2], document, tele-conferencing, and video-conferencing, remote sensing, and remotely piloted vehicles. Remote sensing uses satellite transmitted images for earth-resource applications such as weather forecasting. The efficient storage and transmission of images (gray scale, binary or color) is vital for the control of remotely piloted vehicles such as those in military and vehicles for hazardous waste management.

Image compression techniques can be broadly categorized into two categories namely lossless and lossy compression techniques. The lossless techniques can recover the original image from its compressed form with accurately or with reasonable accuracy; however, the compression ratio is poor. The lossy techniques though achieve higher compression ration but do not recover the original image accurately. However, under certain conditions lossy compressions are adequate. In both types of techniques, the equal loss of information will occur for whole image, as the entire image is compressed with equal compression ratio.

Increasingly, images are acquired through high-resolution cameras, stored on disks, processed locally or remotely, and transmitted electronically across networks. Large number of such images and their huge sizes may result in storage dearth, heavy processing loads, and bandwidth deficiency. As an estimation, the size of a 24-bit color image with dimensions of 512x512 pixels and 72 dpi resolution occupies about 800KByte of storage space. If the same image is acquired through some mega-pixel camera with larger dimension the image may occupy over 2MBytes of storage space. The actual size of the disk space occupied by an image depends upon the operating system and its format. Image can thus be compressed to reduce the storage space requirements, processing loads and transmission time over networks.

The remaining paper is organized as follows: section II presents the background work. Section III discusses transformation based coding. Section IV presents experiments, results and discussions followed by the conclusion.

II. RELATED WORK

Zixiang Xiong et al [3] compared the performance difference between the discrete cosine transform (DCT) and the wavelet transform for both image and video coding. For still images, the wavelet transform outperforms the DCT typically by the order of about 1 dB in peak signal-to-noise ratio. For video coding, the advantage of wavelet schemes is less obvious.

Telagarapu Prabhakar et al [4] applied DCT and DWT for image compression and decompression. The proposed DWT based image compression achieved high PSNR and Compression rate. Further, DCT based image compression offered blocking artifacts at low bit rates as compared to the DWT based image compression.

Harish Jindal and Danvir Mandal [5] analysed the Color Image compression using DCT and DWT for better PSNR & Compression ratio. A comparative study of the performance of DCT & different discrete wavelets in terms of Peak signal-to-noise ratio (PSNR), Mean Square Error (MSE) and overall Compression Ratio has been carried to illustrate the effectiveness of DWT based Image compression method over DCT based methods.

Swanirbhar Majumdar and Anwar Hussain [6] showed that the Wavelet transform based image compression outperformed the discrete cosine transform based compression in terms of compressed output for different quantization levels, as well as the reconstructed image quality. For the same reconstructed image size of 14 Kbytes and equivalent image clarity, discrete wavelet transform based coded image requires less than half transmission bandwidth and storage requirement as compared to DCT based coded image.

III. TRANSFORMATION BASED CODING TECHNIQUES

Modern image processing applications employ transformation coding wherein correlations between adjacent pixels is exploited to compress images [7]. The adjoining pixels of the image are predicted with highest degree of accuracy. The transformation is a lossless process and it transforms the correlated information into uncorrelated coefficients as shown in Figure 1. In transformed domain, image information proves to be more competent rather than the image itself. Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) are two extensively used transformation techniques.

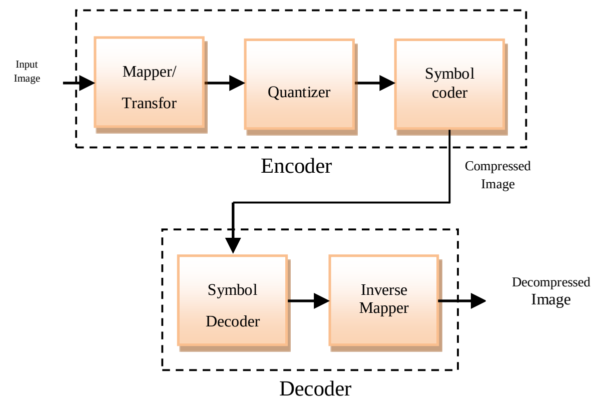

Figure 1: General Image Compression System

In Discrete Cosine Transform (DCT) [8], data is transformed from spatial representation to frequency representation through a mathematical function. The expression for 2D, DCT is given by

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

Where $j, k = 0, 1, 2, \ldots\ldots\ldots\ldots, N\text{-}1$.

The transformation across domains does not change the data and instead permits its compression. For image compression, this is achieved by the DCT transformation of an image into its frequency domain and then removing higher frequency components, which are less sensitive to human eye. The inverse DCT operation reconstructs the original image.

The systematic procedure to compress an image through DCT method is given below:

- The image is divided into small blocks such as blocks of 8x8 pixels.
- Starting from left block representing the top corner then continuing to right and down, to each block, DCT is applied.
- Quantization is used to compress each block.
- The blocks are re-assembled to form the compressed image.

Inverse Discrete Cosine Transform (IDCT) may be applied anytime to the compressed image to reconstruct the original image. The inverse transform is given by

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

Where *m, n =0,1,2,……,N-1* and

$$C[n]=\begin{bmatrix}\sqrt{1/N} & for \quad n=0\\ \sqrt{2/N} & for \quad n=1,2,\ldots\ldots,N-1\end{bmatrix}$$

Through Discrete Wavelet Transform (DWT) a signal can be analyzed in both time and frequency domains [9]. Wavelet comes from fact that they integrate to zero. Wavelets tend to be irregular and asymmetric. Through DWT, higher compression can be achieved as it decomposes time domain signal into different frequency bands through a series of high and low pass filters. The mathematical expression for wavelet transform is given by

$$F[a,b]=\int_{-\infty}^{\infty}f(x)\Psi^{*}(a,b)(x)dx$$

Where $*$ is complex conjugate symbol and Ψ is some function. The steps of the proposed compression algorithm based on DWT are described below:

A. Decompose

Choose a wavelet: choose a level N. Compute the wavelet. Decompose the signals at level N.

B. Threshold Detail Coefficient

For each level from 1 to N, a threshold is selected and hard thresholding is applied to the detail coefficients.

C. Reconstruction

Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

Huffman encoding [10] named after its inventor David Huffman produces an average code length that is shortest. The encoding works subject to the condition that a set of source symbol and probability of the occurrence of each symbol is provided. In this technique, a variable length code table is used to achieving compression. The symbols occurring more often are represented using lesser bits than those, which occur more often.

IV. Experiments, Results and Discussions

Compression of Grayscale Image based on DCT and DWT has be undertaken using MATLAB version 7.11.0 (R2010b) on Windows 7, 64-bit OS, with Intel core i3 processor having 2GB RAM. A set of test images (bmp format) are taken to justify the effectiveness of the algorithm. The experimental results with the proposed compression methods have been arranged in the Table 1 for different Image resolutions.

Image	Image size (pixels)	Technique used	Compression ratio	MSE	PSNR (db)
Image I Jasmine	128x128	DCT	2.6122	4.342	49.4436
		DWT	3.2365	4.165	50.3181
	512x512	DCT	26.5462	0.9732	48.2488
		DWT	30.237	6.1613	40.2341
Image II Lena	128x128	DCT	2.3690	0.0676	59.8335
		DWT	2.9231	1.9067	45.3279
	512x512	DCT	24.5156	2.8152	43.6357
		DWT	29.8172	29.315	33.4599

Table 1: Comparison of DCT and DWT based Compression

From Table 1, it is clear that Image compression based on DWT offers high compression ratio and PSNR with lower MSE for both the image resolutions of the test images of Jasmine and Lena. Also the comparison of the visual results is shown in Figure 2.

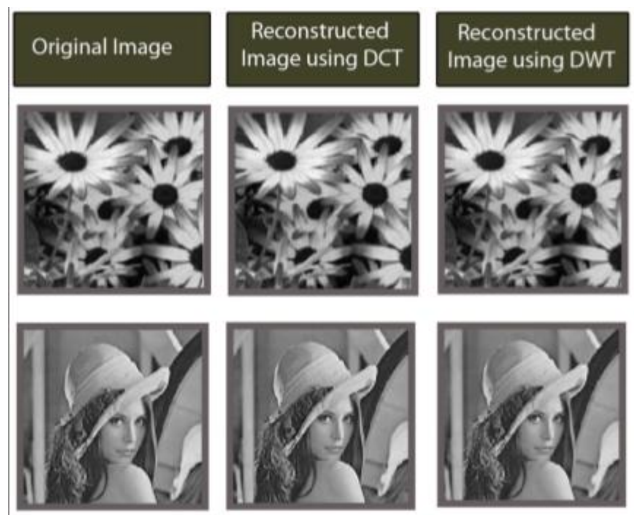

Figure 2: Comparison of the Visual Results

Conclusion

In this paper, Discrete Cosine Transform and Discrete Wavelet Transform for image compression and decompression have been studied. By considering several images as inputs, it has been observed that MSE is low and PSNR is high in DWT based image compression as compared to DCT based compression. From the results, it is concluded that overall performance of DWT is better than DCT on the basis of compression rates. In discrete cosine transform as image needs to be “blocked”, therefore, correlation across the block boundaries is not eliminated. This results in noticeable and annoying “blocking artifacts” particularly at low bit rates. Wavelets are good to represent the point singularities and it cannot represent line singularities. This study can further be extended for line singularities with new transform named Ridgelet Transform.

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