2-Dimensional Image Compression using DCT and DWT Techniques

Harmandeep Singh Chandi, V. K. Banga

Abstract—Image compression has become an active area of research in the field of Image processing particularly in the applications of medical and space sciences. There are many image compression techniques available, but still there is need to develop faster, and more strong and healthy techniques to compress images. Because, main difficulties in developing compression algorithms for image is the need for preserving the minutiae i.e. ridges endings and bifurcations, which are subsequently used in identifications. To achieve high compression ratios while retaining these fine details, wavelet packet are used. Recently, the wavelet transform has emerged as a cutting edge technology, within the field of image compression research. This paper is focused on selecting the most appropriate wavelet transform for a given type of image compression. In this paper we have analyzed the behavior of different type of transforms with different type of images and identified the most appropriate transform that can perform optimum compression for a given type of imaging. To analyze the performance of the wavelet transform with the images at constant PSNR, we calculated MSE and their respective percentage compression.

Keywords—Image compression, Wavelet Transform, PSNR, MSE.

I. INTRODUCTION

Our computer is becoming more and more powerful day by day, and it results the use of digital images is increasing rapidly. Along with this increasing use of digital images comes the serious issue of storing and transferring the large amount of data representing the images because the uncompressed multimedia (graphics, audio and video) data requires considerable storage capacity and transmission bandwidth. One of the important factors for image storage or transmission over any communication media is the image compression. Compression makes it possible for creating file sizes of manageable, storable and transmittable dimensions. A 4 MB image will take more than a minute to download using a 64kbps channel, whereas, if the image is compressed with a ratio of 10:1, it will have a size of 400KB and will take about 6 seconds to download. In other words we can say that compression is minimizing the size of bytes of a graphic file without degrading the quality of image. The image is consists of large amount of redundant data i.e. it contains the same information repetitively. According to Saha [1] [2] there are two different types of redundancy relevant to images spatial redundancy and spectral redundancy. By using data compression techniques, it is possible to remove some amount of redundant information. The will save some amount of file size and allows more images to be stored in a certain amount of disk or memory space. It also reduces the necessary time for images to be transmits over the internet or downloaded from web pages.

The scheme of image compression is not new at all. With the discovery of Discrete Cosine Transform (DCT) in 1974 is important achievement for those who works in image compression. The DCT is advanced version of Fourier Cosine series. The DCT technique performs same task as fourier series like converting a signal into elementary frequency components. But, DCT can be computed on real-valued and provides a better approximation of a signal with fewer coefficients. While in compression, the main challenging task/problem for researchers is de-noising because noise removal introduces artifacts and causes blurring of the images. The compression ratio is different before and after de-noising the image. To increase compression ratio image must be de-noised first and then compressed it. Many different methodologies are used for noise reduction (or de-noising) giving an insight as to which algorithm should be used to find the most reliable estimate of the original image data given its degraded version. Various thresholding techniques based on wavelet domain-filtering techniques i.e. Wavelet thresholding is an effective method of de-noising the noisy signals and it will take an important role in de-noising the images [5][6][7][8]. There are two basic approaches used for image de-noising, spatial filtering methods & transform do-main filtering. Again spatial filtering is further classified as Non-linear and linear filters. Transform domain filtering can be divided into data adaptive & Non-adaptive. Non-adaptive transforms are more popular, can be classified as wavelet domain & spatial frequency domain.

This paper uses a wavelet based approach for effective image compression due to the following advantages of the wavelets.

- Wavelet coding approaches at higher compression avoid blocking artifacts.
- Wavelet coding is better matched to the Human Visual System (HVS) characteristics.
- Wavelet based compressions facilitate parametric gain control for image softening and sharpening.

Harmandeep Singh Chandi is working as a Head of Electronics and Communication Engineering department in Chandigarh University, Gharuan, Punjab, India. (e-mail: harmandeep.cgc@gmail.com).

Dr. V. K. Banga is working as a Professor in Electronics and Communication Engineering department of Amritsar College of Engineering and Technology, Amritsar, Punjab, India. (e-mail: vijaykumar.banga@gmail.com).
• Wavelet-based coding is more robust under transmission and decoding errors, and also allows progressive transmission of images.
• Wavelet compression is very competent at low bit rates.
• Wavelets offer an efficient decomposition of signals earlier to compression.

Since the Haar Transform is memory efficient, exactly reversible without the edge effects, it is fast and simple. As such the Haar Transform technique is widely used these days in wavelet analysis. Fast Haar Transform is one of the algorithms which can reduce the tedious work of calculations. One of the earliest versions of FHT is included in HT [5]. In section 2, the Haar Transform has been explained. In section 3, Discrete Cosine Transform is presented with the proposed algorithm for 2D images. Results and simulation are given in section 4 followed by conclusion in 5.

II. IMAGE COMPRESSION TECHNIQUES

Image can be mostly compressed by two methods:
1. JPEG based Discrete Cosine Transform (DCT)
2. Discrete Wavelet Transform (DWT)

Both JPEG and wavelet belong to the general class of “transformed based lossy compression techniques. These techniques involved three steps:
• Transformation
• Quantization
• Encoding.

Transformation is a lossless step in which image is transformed from the grayscale values in the special domain to coefficients in some other domain. No loss of information occurs in the transformation step. Quantization is the step in which loss of information occurs. It attempts to preserve the more important coefficients, while less important coefficients are roughly approximated, often as zero. Finally, these quantized coefficients are encoded. This is also a lossless step in which the quantized coefficients are compactly represented for efficient storage or transmission of the image.

2.1 Discrete Cosine Transform (DCT)

The discrete cosine transform (DCT) helps separate the image into parts (or spectral sub-bands) of differing importance (with respect to the image's visual quality). The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain (Fig 1)

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

Where: j, k = 0, 1, 2,…., N - 1 and. The inverse transform is defined as:

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

Fig.1 Transformation of function into DCT

In particular, a DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even), where in some variants the input and/or output data are shifted by half a sample. There are eight standard DCT variants, of which four are common.

The two-dimensional DCT of an M-by-N matrix A is defined as follows:

Wavelet transform has emerged as very powerful tool for data compression. It provides a vehicle for image processing applications, because it has ability of to take into an account Human Visual System (HVS) characteristics, good energy compaction capabilities, and under transmission & decoding, and also it is more robust under transmission & decoding error, which results in a high compression ratio. In addition to these wavelets transform compression provides a superior image quality at low bit rates [18], since there is no need of blocking the image. The Practical implementation of wavelet compression schemes is very similar to that of sub-band coding schemes. As in case sub-band coding, we decompose the signal (analysis) using filter banks. The output of the filter banks are down sampled, quantized, and encoded. The decoder decodes the coded representation, up samples, and recomposes the signal. [9][10].

Wavelet analysis can be used to divide the information of an image into approximation and detail sub signals. The approximation sub-signal shows the general trend of pixel values, and three detail sub-signal shows the vertical, horizontal and diagonal details or changes in the images. If these details are very small then they can be set to zero without significantly changing the image. The value below which, detail are considered small enough to be set to zero known as threshold. The greater the number of zeros the greater the compression ratio. The amount of information retained by an image after compression and decompression is known as the retained energy and this is proportional to the sum of the square of the pixel values. If the energy retained 100% then the compression is known as lossless as the image.
can be reconstructed exactly. This occurs when the threshold value is set to zero, meaning that the detail has not been changed. If any values are changed then energy will be lost and this known as lossy compression. Ideally, during compression the number of zeros and the energy retention will be as high as possible. However, as more zeroes are obtained more energy is lost, so a balance between the two needs to be found \cite{1} \cite{13}.

In addition to the above properties of wavelet transform, The Haar wavelet transformation is composed of a sequence of low-pass and high-pass filters, known as a filter bank. The low pass filter per-forms an averaging/blurring operation, and is expressed as:

$$H = \frac{1}{\sqrt{2}} (1, 1)$$

and the high-pass filter performs a differencing operation and can be expressed as:

$$G = \frac{1}{\sqrt{2}} (1,-1)$$

**Decomposition Process:**

The image is high and low-pass filtered along the rows. The results of each filter are down-sampled by two. Each of the sub-signals is then again high and low-pass filtered, but now along the column data and the results is again down-sampled by two.

![Decomposition Process Diagram](image1)

**Composition Process:**

The four sub-images are up-sampled and then filtered with the corresponding inverse filters along the columns. The result of the last step is added together and we have the original image again, with no information loss.

![Composition Process Diagram](image2)

**III. DESIGN METRICS**

It is natural to raise the question of how much an image can be compressed and still preserve sufficient information for a given clinical application. This section discusses some parameters used to measure the trade-off between image quality and compression ratio. Compression ratio is defined as the nominal bit depth of the original image in bits per pixel (bpp) divided by the bpp necessary to store the compressed image. Digital image compression techniques are examined with various metrics. Among those the most important one is Peak Signal to Noise Ratio (PSNR) which will express the quality. There exists another property which expresses the quality, that is, Mean Square Error (MSE). PSNR is inversely proportional to MSE. The other important metric is Compression Ratio, which express the amount of compression embedded in the technique. In theory, it was observed that PSNR and Compression ratios are inversely related. The other metrics are Encoding Time, Decoding Time and Transforming Time.

**Mean Square Error:** Among the quantitative measures, a class of criteria used often is called the mean square criteria. It refers to some sort of average or sum (or integral) of squares of the error between two images.
MSE for monochrome image

\[ \frac{1}{N^2} \sum_i \sum_j (X(i,j) - Y(i,j))^2 \]

MSE for color image

\[ \frac{1}{N^2} \sum_i \sum_j \left( (r(i,j) - r'(i,j))^2 + (g(i,j) - g'(i,j))^2 + (b(i,j) - b'(i,j))^2 \right) \]

where \( r(i,j) \), \( g(i,j) \) and \( b(i,j) \) represents a color pixel in location \((i,j)\) of the original image, \( r'(i,j) \), \( g'(i,j) \) and \( b'(i,j) \) represents color pixel of the reconstructed image and \( N \times N \) denotes the size of the pixels of these color images.

**Signal to Noise Ratio:** In many applications the Mean Square Error is expressed in terms of a Signal to Noise Ratio (SNR) which is defined in decibels (dB) as

\[ \text{SNR} = 10 \log_{10} \left( \frac{\sigma^2}{\sigma'^2} \right) \]

Where \( \sigma^2 \) is the variance of the desired image and \( \sigma'^2 \) is average variance.

**Peak Signal to Noise Ratio:** Peak Signal to Noise Ratio is defined as the ratio between signal variance and reconstruction error variance. Mean Square Error, Peak Signal to Noise Ratio and Compression Ratios are calculated from the following expressions.

\[ \text{PSNR} = 10 \log_{10} \left( \frac{255^2}{\text{MSE}} \right) \]

**Compression Ratio:** Compression ratio is defined as the ratio between the original image size and compressed image size.

\[ \text{Compression Ratio} = \frac{\text{Uncompressed image size}}{\text{Compressed Image size}} \]

**Encoding Time, Decoding Time and Transforming Time:** Any compression system uses one of the encoding techniques to encode the input information. The encoding operation is very crucial for the success of the compression system. It involves the representation of the input information in a form suitable for storage and transmission. The time required to perform this operation is referred to as encoding time. The reverse process to encoding is decoding and the corresponding time required to decode an encoded data is decoding time. In general, the information to be compressed will be represented in time or spatial domain. To compress the data, it was observed that it is convenient to represent the data in frequency domain. Hence the information in time domain needs to be converted into frequency domain. For that, one of the transforming techniques will be used. Again it involves some consumption of time. This time is referred to as transforming time. These times are measured in seconds.

**VI. SIMULATION RESULTS OF DCT & DWT TECHNIQUE**

For Simulation, we apply DCT technique on three different images by choosing 8x8 block size. These three original images and output images are shown below. All three images have different size.

![Original and Compressed Images](image1)

**Figure 4:** Comparison between original image and DCT based compressed image.

In Fig 4 we can see the reconstructed image is not exact as the original image. But all are identical to their original image. DCT has block artifacts. We can see that in compressed image of baby, there are block artifacts on her hand’s picture. If we choose small size of block then the block artifacts is minimized. By using 8x8 block size and applying quantization we minimized the each pixel value 0 to 32 from 0 to 256. So one pixel needs 5 bits to represent its value on behalf of 8 bits. Thus we achieve Cr=8/5=1.6 which is quite reasonable.
In DWT, we get very high compression ratio, we lose minimum amount of information. But if we do more than one level then we get more compression ratio but the reconstructed image is not identical to original image. MSE is greater if DWT apply more than one level. In nowadays, this technique is use in JPEG2000 [1] algorithm as one step of its. We think that the we get better result in DWT. But that’s not always true. This better result comes in cost of processing power. As we did earlier in DCT, this technique is applied on three images and results of these images are presented here.

![Original Image](image1.png)  ![Compressed Image](image2.png)

Leena  Leena

Baby  Baby

Penguins  Penguins

The output images show that there is no any block artifacts. Because we apply DWT on whole image, not on block. We got Cr=1.9 to 2.3 compression ratio.

V. CONCLUSION

It is hereby to note that the compression ratio is much satisfactory in the case of Haar transformation but the compression ratio is calculated on the reduced scale. There is one point to note that the compression ratio is also dependent on the type of Images. The speed of the compression is also dependent on the processor and the type of language used to implement the algorithm i.e. the same algorithm when implemented on the lower level language it takes smaller amount of time than implemented on the high level language. The main conclusion that can be drawn from the above facts that the compression ratios are also dependent on the file size and the algorithms used. Better compression ratios can be achieved by using the appropriate file size. Lastly the high compression ratios can be achieved selecting the nature of the images.

REFERENCES