Journal of Information Engineering and Applications
ISSN 2224-5758 (print) ISSN 2224-896X (online)
Vol 1, No.2, 2011
www.iiste.org

Comparative Analysis between DCT & DWT Techniques of Image Compression

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Abstract

Image compression is a method through which we can reduce the storage space of images, videos which will helpful to increase storage and transmission process's performance. In image compression, we do not only concentrate on reducing size but also concentrate on doing it without losing quality and information of image. In this paper, two image compression techniques are simulated. The first technique is based on Discrete Cosine Transform (DCT) and the second one is based on Discrete Wavelet Transform (DWT). The results of simulation are shown and compared different quality parameters of its by applying on various images

Keywords: DCT, DWT, Image compression, Image processing

1. Introduction

In modern day, many applications need large number of images for solving problems. Digital image [1] can be store on disk. This storing space of image is also important. Because less memory space means less time of required to processing for image. Here the concept of image compression comes. "Image compression[1] means reduced the amount of data required to represent a digital image". There are many applications [2] where the image compression is used to effectively increased efficiency and performance. Application are like Health Industries, Retail Stores, Federal Government Agencies, Security Industries, Museums and Galleries etc.

1.1 Requirement for image compression:

An image compression system needs to have at least the following two components:

a. Encoding System

b. Decoding System

Encoding System takes an original image as input and after processing on this, it gives compressed image as output. While Decoding System takes an compressed image as input and gives the image as output which is more identical to original image.

Nowadays, DCT[1,3,4,5] and DWT[1,3,7] are the most popular techniques for image compression. Both techniques are frequency based techniques, not spatial based. Both techniques have its' own advantages and disadvantage. Like DWT gives better compression ratio [1,3] without losing more information of image but it need more processing power. While in DCT need low processing power but it has blocks artifacts means loss of some information. Our main goal is to analyze both techniques and comparing its results.

2. DCT Technique

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:

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

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

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

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

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

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

$$y[j,k] = C[j]C[k]\sum_{m=0}^{N-1}\sum_{n=1}^{N-1} x[m,n]\cos[\frac{(2m+1)j\pi}{2N}]\cos[\frac{(2n+1)k\pi}{2N}] \quad (3)$$

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

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

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.

2.1Encoding 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 lossy step. So selection of quantization value or quantization matrix[10] 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.

$$Cr = \frac{n1}{n2} \tag{5}$$

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.

$$MSE = \sum_{i=1}^{M}\sum_{j=1}^{N}\left(x(i,j) - x'(i,j)\right)^2 \tag{6}$$

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.

2.3 Simulation Results:

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 Image | **Compressed Image**

Logo

Logo

Baby

Baby

Penguins

Penguins

Fig 1 Comparison between original image and DCT based compressed image.

In Fig 1 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.

The following table shows MSE of each of three images. It shows how much information we have lost due to our compression technique. There is also shown total MSE of original image with zero image. So we can analyze that how many percentage of the information we loss out of total information .

Table 1 MSE of output images of DCT technique

Image name	**MSE**	**Total (MSE of original image with Zero Image)**
Logo	15368164	2.19×10^{10}
Baby	10289294	2.11×10^{10}
Penguins	17012605	2.10×10^{10}

2.DWT Technique

Wavelet analysis [1,3,7] can be used divided the information of an image into approximation and detailed sub signal[3]. The approximation sub signal shows the general trend of pixel value, and three detailed sub signal show vertical, horizontal and diagonal details or changes in image. If these detail is very small than they can be set to zero without significantly changing the image. If the number of zeroes is greater than the compression ratio is also greater. There is two types of wavelet is used. First one is Continues wavelet transform[1] and second one is Discrete wavelet transform.[1] Wavelet analysis is computed by filter bank. There is two type of filter

1) High pass filter[1]: high frequency information is kept, low frequency information is lost.

2) Low pass filter[1]: law frequency information is kept, high frequency information is lost.

So signal is effectively decomposed into two parts, a detailed part(high frequency) and approximation part(law frequency). Level 1 detail is horizontal detail, level2 detail is vertical detail and level 3 detail is diagonal detail of the image signal.

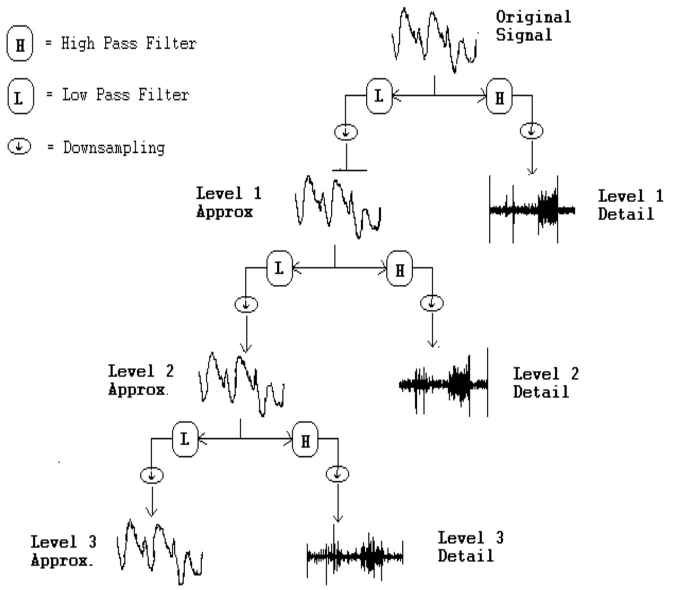


Fig 2 Visual representation of the decomposition of a one dimensional input source using a wavelet transformation using three passes.

3.1Encoding System

Six steps process for compressing an image with Discrete wavelet transform is shown below.

Step1.First original image have to been passed through high pass filter and low pass filter by applying filter on each row.

Step2.now output of the both image l1 and h1 are combine into t1=[l1 h1].

Step3. T1 is down sampled by 2.

Step4. Now, again T1 has been passed through high pass filter and low filter by applying on each column.

Step5. Output of the step4 is supposed l2 and h2. Then l2 and h2 is combine into t3=$\begin{bmatrix} l2 \\ h2 \end{bmatrix}$.

Step6. Now down sampled t3 by 2.This is our compressed image.

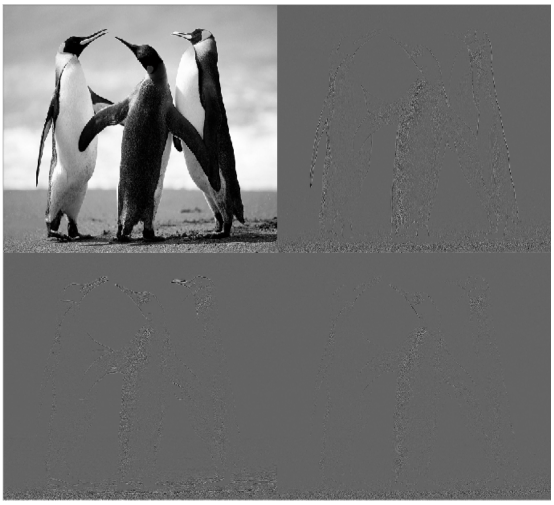


Fig 3. Compressed Image(penguins)

In fig 3 there are shown a resulted image after applying encoding process. In this fig we can see four blocks. The first upper half block shows the approximation, while second upper half is shows

ISSN 2224-5758 (print) ISSN 2224-896X (online)
Vol 1, No.2, 2011

horizontal detail. First lower level block shows vertical detail and second lower level block shows diagonal detail.

In algorithm there is shown one level discrete wavelet transform. You can also increase the level of DWT by applying this process more than one time. Second and third level DWT gives the better compression ratio. But it will come with loss of some information. First level DWT is quite reasonable for both achieving high compression ratio and also got quality (less MSE). We can get Cr = 2 to 2.5 which is very beneficial for us.

3.2 Decoding System.

Here decoding system's process is not exact reverse of encoding system's process. Steps are shown below.

Step1.Extract low pass filter image and high pass filter image from compressed image simply by taking upper half rectangle of matrix is low pass filter image and down half rectangle is high pass filter image

Step2. Both images are up sampled by 2.

Step3.Now we take the summation of both images into one image called r1.

Step4. Then again extract low pass filter image and high pass filter image by simply dividing vertically. First half is low pass filtered image. And second half is high pass filter image.

Step5. Take summation of both images that is out reconstructed image.

Though 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.

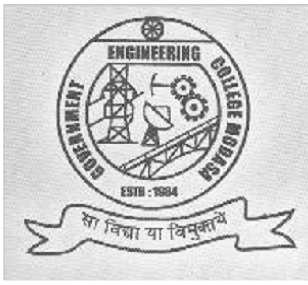
3.3 Simulation Results:

As we did earlier in DCT, this technique is applied on three images and results of these images are presented here.

Original Image

Logo

Compressed Image



Logo

Baby

Baby

Penguins

Penguins

Fig 4 Comparison between original image and DWT based compressed image.

Table 2 MSE of output images of DWT technique

Image name	**MSE**	**Total (MSE of original image with Zero Image)**
Logo	7.23 x 10^6	2.19 x 10^{10}
Baby	1.36 x 10^6	2.11 x 10^{10}
Penguins	8.05 x 10^6	2.10 x 10^{10}

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. MSE of reconstructed images are also less as shown in table 2.

4. Result analysis comparison between DCT and DWT techniques

For DCT technique we can achieve the Cr=1.6 compression ratio.

For DWT technique we can achieve the Cr=1.9 to 2.3 compression ratio.

Now using the table I and table II we draw two graphs for analyze the data.

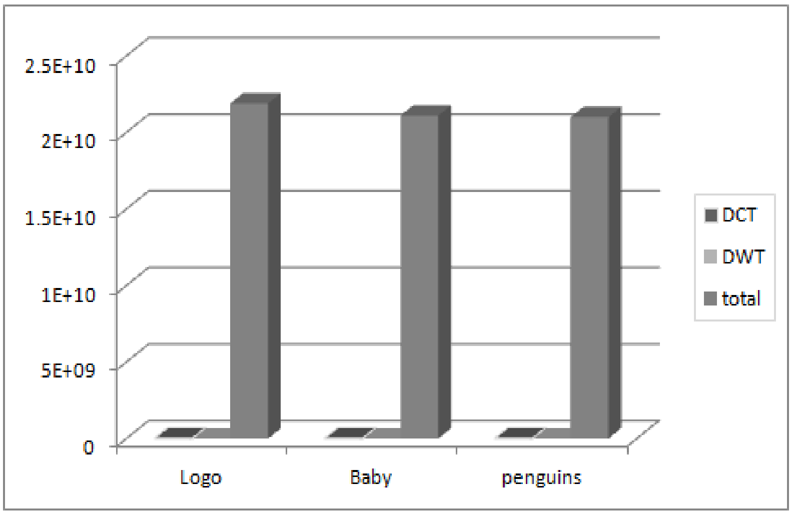


Fig 5 Graph for DCT, DWT information loses and total information

Fig 5's graph shows the comparison of DCT and DWT compressed image with its original information. We can say that lose of information is quite negligible in both technique.

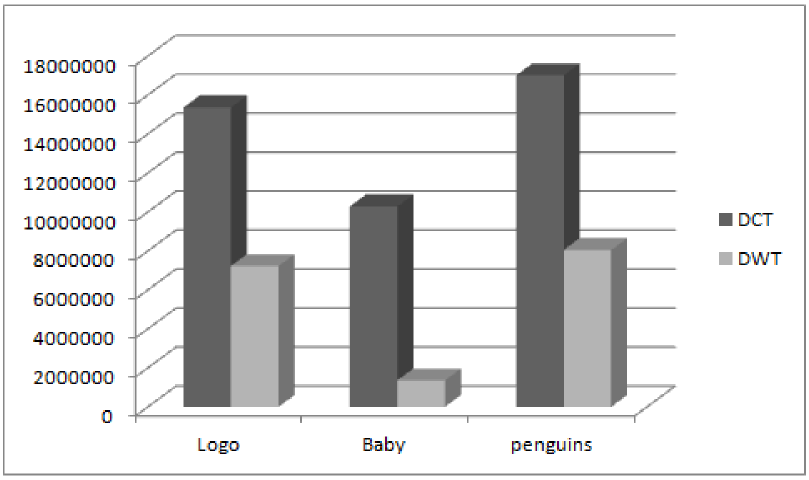


Fig 6 Graph for comparing DCT, DWT information lose

Fig 6's graph shows the comparison of lost of information in DCT and DWT technique. From this we conclude that in DWT information loss is less than information loss in DCT. So quality wise the DWT technique is better than DCT technique, but in performance time wise DCT is better than DWT technique.

5. Conclusion

By doing these experiments we conclude that both techniques have its' own advantage and disadvantage. But, both techniques are quite efficient for image compression. We can get quite reasonable compression ratio without loss of much important information. Though our experiments show that DWT[1,3,7] technique is much efficient than DCT[1,3,5,6] technique in quality and efficiency wise. But in performance time wise DCT is better than DWT

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