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Analysis of Combined DCT-Vector Quantization Techniques for Image Compression

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Abstract — *The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or* transmit *data in an efficient form. Any image compression technique does not concentrate on reducing storage amount of bits but also concentrate on not to lose quality of image. DCT is the more efficient method of image compression because it has properties of good energy compaction and correlation reduction. We can merge DCT with Vector Quantization technique. This study presents you the simulation of DCT-VQ image compression technique and result of various parameters is compared with JPEG*

Keywords- *DCT, Vector Quantization, MSE, Image Compression, Image Processing*

I. 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. Applications are like Health Industries, Retail Stores, Federal Government Agencies, Security Industries, Museums and Galleries etc.

Image compression is the process of encoding an image to reduce the number of bytes required to store or transmit the image. Compression is achieved by the removal of redundancies which found in data. There are three type of redundancies can be removed.

1) Coding redundancy
2) Inter-pixel redundancy
3) psycho-visual redundancy

When we use code to represent data whose length is more than optimal code then this type of redundancy is called coding redundancy. Inter-pixel redundancy, which results from correlations between the pixels of an image. Next, we eliminate the data which is ignored by human visual system. This type of redundancy is called psycho-visual redundancy [1].

Process of Image Compression

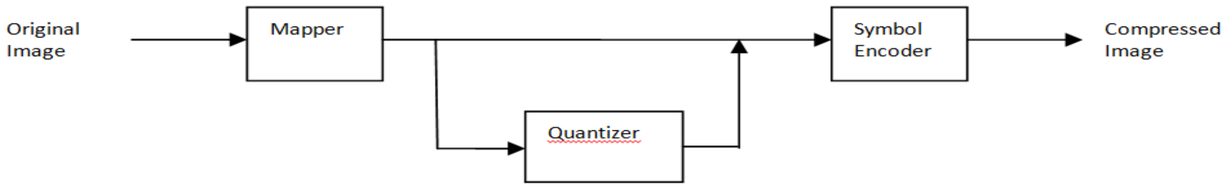


Figure 1 Encoder for Image Compression

1) Block mapper transforms input image into a format designed to reduce inter-pixel redundancies.
2) Quantizer block is used to transform mapper block output into predefined fidelity criterion.
3) Symbol coder creates a code for output of quantizer block

Quantizer block is not present in losseless image compression process, while in lossy image compression it is present. This block's process loss some degree of amount of information, but it is main part of compression process which help us to achieve the high amount of compression efficiency.

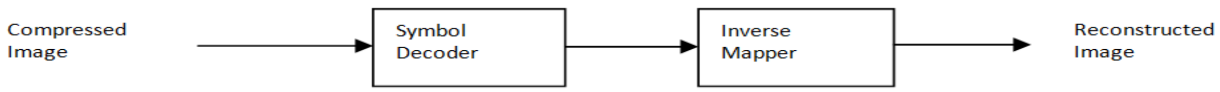


Figure 2 Decoder for Image Compression

Decompression of image means reconstruct of original image from compressed. Steps of decoding

1). Symbol decoder is performs the inverse function of symbol encoder
2). Inverse mapper is performs inverse function of mapper block

Nowadays, DCT[1,3,4,5] is the most popular technique for image compression. This technique is frequency based technique, not spatial based. In DCT need low processing power but it has blocks artifacts means loss of some information. Our main goal is to combine DCT with Vector Quantization technique and analyze the results.

II. 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:

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

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

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

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

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

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

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

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

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

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] affects 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.

$$CR = n1/n2 \tag{5}$$

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.

III. VECTOR QUANTIZATION

Vector quantization is an lossy type image compressing technique. In this technique some information may be loss due to quantization. First Image is divided into fixed size block called training set and also creates a codebook which has indexed image block of the same size of representing types of image block. Then it prepares a string for image by finding corresponding block index and arranging them.

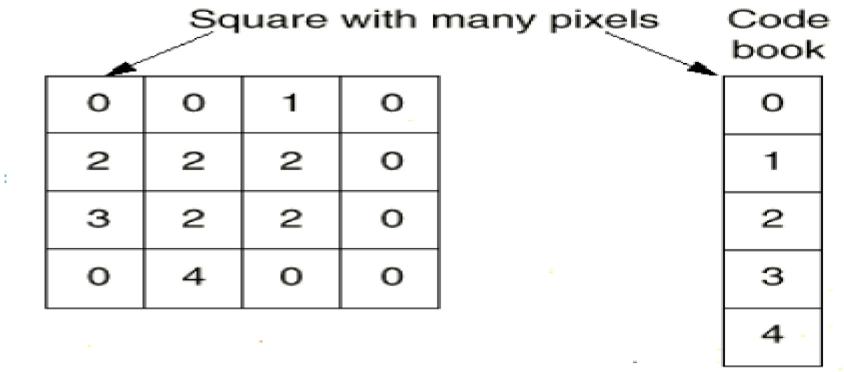


Figure 3 Image representations in Vector quantization with its codebook

Above example in fig are given in Digital Image Processing book of Gonzalez. There are shown one image with its block and its codebook. There are also shown corresponding block index from codebook or closest match block index.

Instead of transmitting pixel value we simple transmit codebook and encoded string "0 0 1 0 2 2 2 0 3 2 2 0 0 4 0 0" so at the decoded side we can reconstruct original image by using this encoded string and codebook by putting the corresponding block from codebook.

IV. COMBINATION OF DCT-VECTOR QUANTIZATION

We can apply first DCT by dividing block into 8x8 and then apply vector quantization on it. As DCT transform the image frequency into lower, we can use vector quantization efficiently

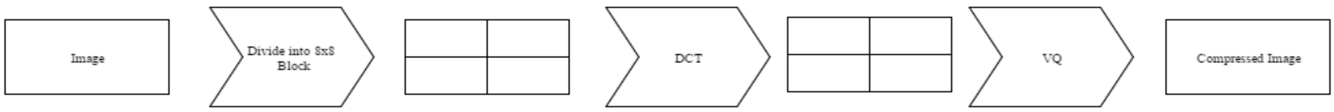


Figure 4 Encoding scheme of DCT-VQ technique

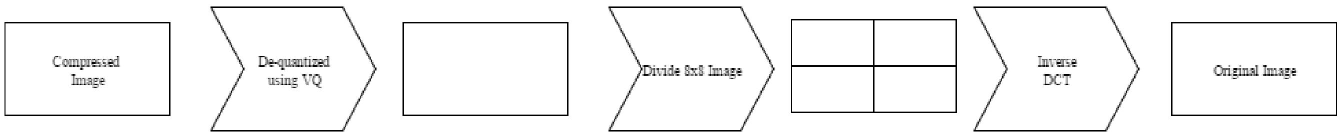
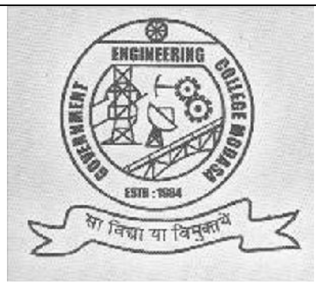


Figure 5 decoding scheme of DCT-VQ technique

4.1 Simulation result

As shown above figures we apply DCT-VQ compression technique these 3 Original Images and output images are shown below. These entire three images have different size

Original Image	Compressed Image (DCT)	Compressed Image (DCT-VQ)
 Logo	 Logo	 Logo

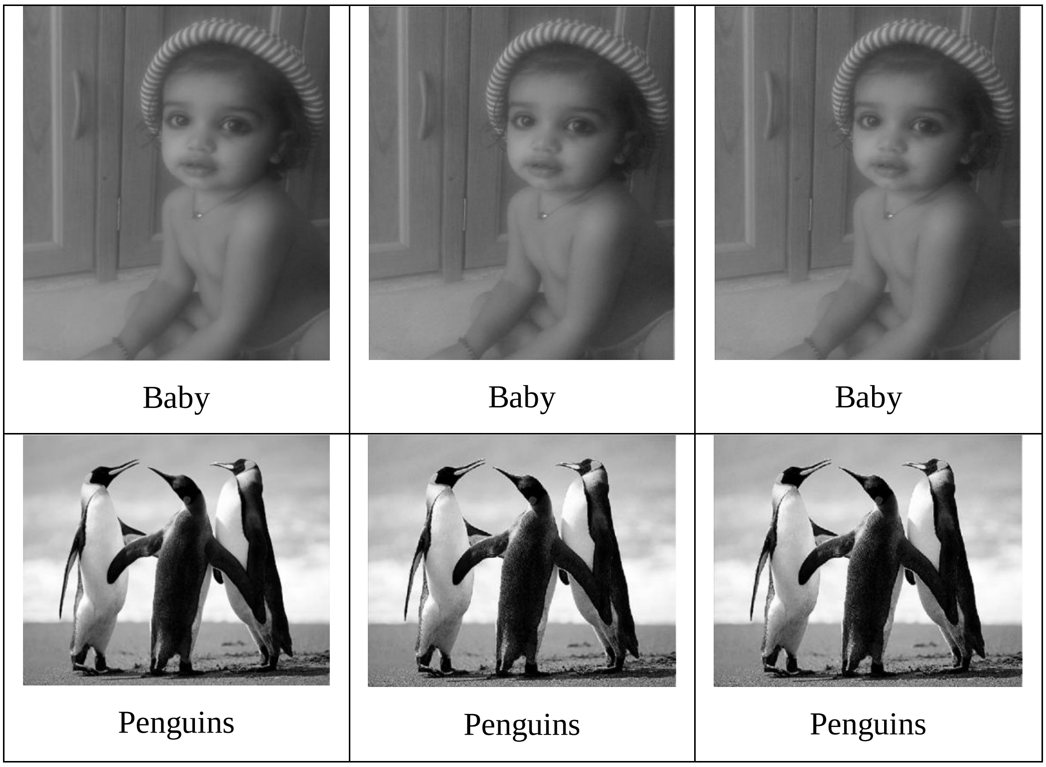


Figure 6 Comparisons between Original Image and Compressed Image

Table 4.6 MSE of output images of DWT technique

Image name	**MSE(DCT)**	**MSE (DCT-VQ)**	**Total (MSE of original image with Zero Image)**
Logo	1.36 x 10^6	1.67 x 10^6	2.19 x 10^{10}
Baby	8.05 x 10^6	8.11 x 10^6	2.11 x 10^{10}
Penguins	7.23 x 10^6	7.45 x 10^6	2.10 x 10^{10}

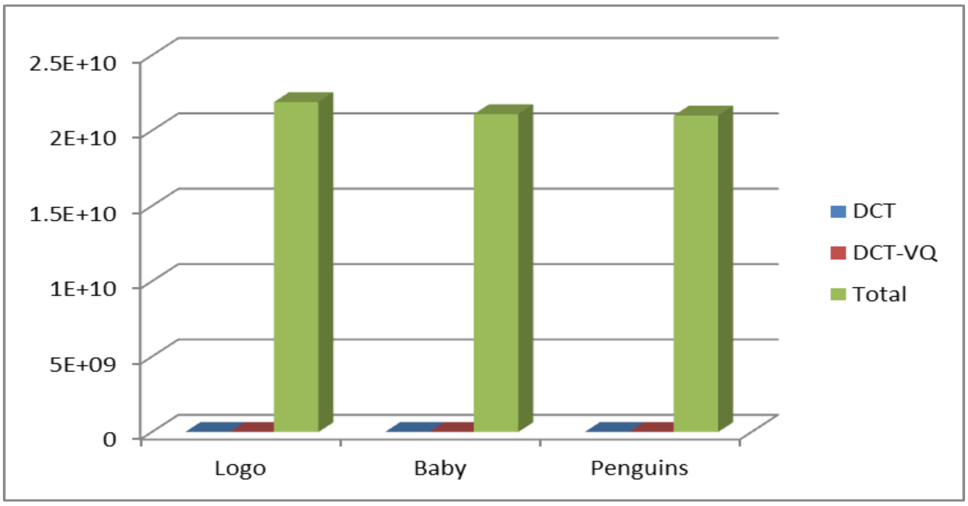


Figure 7 Graph for DCT, DCT-VQ information loses and total information

We can see that both DCT and DCT-VQ techniques have very less information loss. That thing we also can see that in images shown in Figure 6.

Now let's compare DCT and DCT-VQ results

We can see the DCT-VQ Technique is not losing much information as compared to DCT technique. Here we have used 8x8 codebook size for vector quantization so we are getting 8 times more compression ratio than DCT.

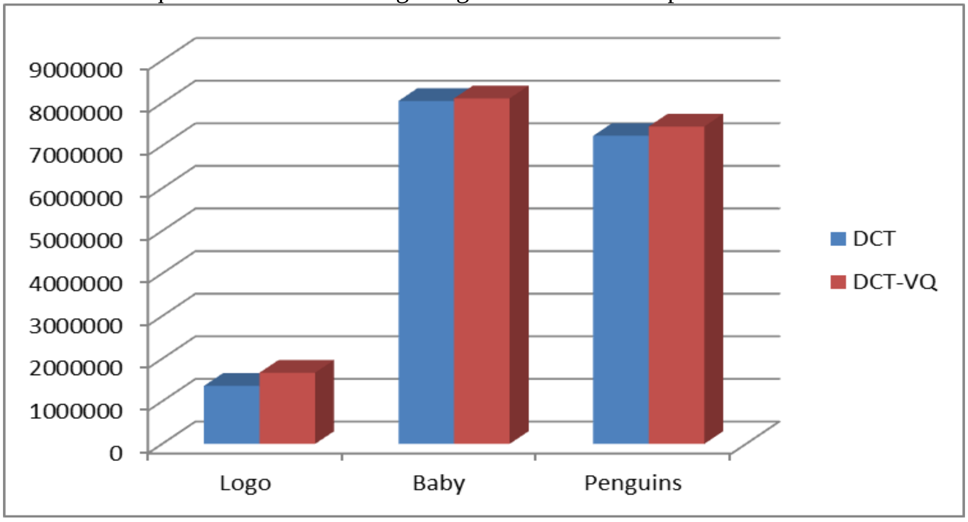


Fig 4.8 Graph for comparing DCT, DCT-VQ information loss

V. CONCLUSION

Both techniques DCT and DCT-VQ are quite efficient for image compression. We can get quite reasonable compression ratio without loss of much important information through these techniques. Though our experiments show that DCT-VQ[technique is much efficient than DCT[1,3,5,6] technique in terms of compression ratio but of course we losing some negligible information. We can increase code book size to see what effect it does but it is another scope of work.In summary DCT-VQ techniques is much better than the DCT.

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