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Image Compression

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***Abstract*—** this paper will explain image compression algorithm using discrete cosine transform. The code architecture is established with the explanation of the different steps. The results are then established in order to compare the realized work with JPEG. The compression algorithm of an image is separated into several steps, the first one is the transformation of the image using the *Discrete Cosine Transform (DCT2 transform)*. This operation is followed by a quantization of the resulting matrix, then packing of quantized bits in order to write to a file with a header announcing the image quality with series of bytes saved into the text file. All the codes are done using the MATLAB.

***Keywords*— Compression, DCT, Huffman, Quantization, PSNR, MSE, JPEG)**

I. Introduction

The objective of image compression is to lower irrelevance and redundancy of the image data for image storage or data transmission in an efficient way. It is about reducing the number of bits required to store an image. Image compression can either be lossy or lossless. This project applied feature extractor with the image quality ranges from 1 to 10 depending on the user's quality choice. The compression algorithm in this project is divided into the steps summarized by the block diagram below in figure 3.

Figure 1: Original Image- Lena

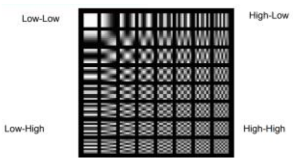

Figure 2: Two dimensional DCT basis functions

II. DESCRIPTION OF THE PROCESS

A. *Block diagram*

The block diagram below gives an overview of the steps in implementing the image compression task in this project.

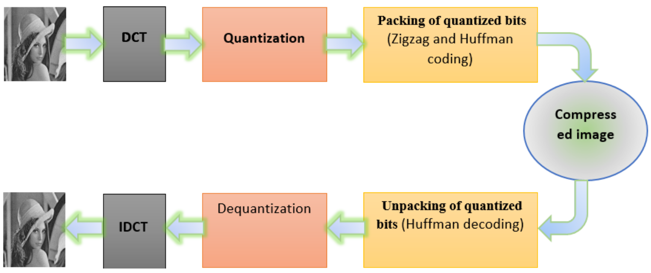

Figure 2: Block diagram of the Procedure

The image of size 512×512 is transformed by *dct2* command to process the blocks of pixels, working from left to right, top to bottom in a zigzag manner. The dct2 command operation is normalized by the size of the original image, thereafter each dct coefficient is compressed through the quantization process, the array of compressed bocks that make up the quantized DCT coefficients of the image are packed using Huffman encoding scheme. Next thing is that these sequence of bits are written to a text file with a header announcing the image quality. For reconstruction phase, just as can be seen in the block diagram, the header and bytes are read, and unpacking of the stream of bits is done, this is then followed by dequantization, DCT2 inverse transform and finally the image is recovered.

B. *Discrete Cosine Transform*

DCT is an algorithm that samples an image at regular intervals, analyzes the frequency components in the sample, and reject those frequencies that will not affect the image as the human eye perceives it. DCT2 formula is given by

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \cos\left(\frac{\pi(2m+1)}{2M}\right) \cos\left(\frac{\pi(2n+1)q}{2N}\right) \quad (1)$$

$$\text{Where } \alpha_p = \begin{cases} \frac{1}{\sqrt{M}}, & if\ p = 0 \\ \sqrt{\frac{2}{M}}, & if\ 1 \le p \le M-1 \end{cases}$$

$$\alpha_q = \begin{cases} \frac{1}{\sqrt{N}}, & if\ q = 0 \\ \sqrt{\frac{2}{N}}, & if\ 1 \le p \le N-1 \end{cases}$$

C. *Vector Quantization*

Quantization is the step where most of the compression operation takes place based on the defined matrix with preference given to low frequency and less attention to the AC DCT coefficients that human eyes cannot easily perceive their spatial change. Masks is used as a geometric filters to select a region of an image by multiplying the matrix of the original image by a matrix of equal size contained in the region of our interest .This formula helps us to select the region of the image Lena obtained from dct coefficients. The step is applied by first is to create a matrix of the same dimensions filled with zeros, modify the matrix to contains in a dimension less than the original image. And then multiply the image by the mask.

To design this matrix, we used the formula.

$$(i - Cx)^2 + (j - Cy)^2 \quad (2)$$

Where: Cx and Cy are the coordinates of the central coefficients of the DCT matrix.

i and j represent the coordinates of each coefficient of the quantization matrix

D. *Packing of quantized bits and Unpacking of quantized bits.*

Each symbol is encoded with a variable-length code based on their statistical probability of frequency. Call a function which will find the pixel value which is non-repeated, pixels in the image are treated as symbols.Meaning that each pixel of the image is encoded in one byte.

E. Writing to a file with a header announcing the image size + series of bytes of packed bits

All the pixels are concatenated in a specific sequence, this sequence follows the disposition of the pixels in a vector (the quantized matrix is transformed into a vector). This long sequence will be saved in a text file after adding a header to the reconstruction part.

F. Reading of the header and bytes

The content of file is first transformed into a binary sequence, the decoding part uses the fact that each value of the file is coded on one byte.

G. Unquantization and DCT2 inverse trasnform

In order to reconstruct the image, I followed the order of operation given in the block diagram in fig. 3 above. The last operation to be applied on each pixel is the Inverse Discrete Cosine Transform using the idct2 command on MATLAB and multiplying the result by the size of the image for normalization.

III. RESULTS

This section shows the results of the DCT, quantization and Huffman algorithm for the compression of the 512x512 image of Lena depending on the quality of choice the user made. The MSE is the cumulative squared error between the reconstructed and the original image whereas PSNR measures the peak error hence it tells us about the quality of the reconstructed image. A low value of MSE means a low error image. Table 1 summarized a few results of PSNR, MSE and CR.

Image Size=512x512
Compression Quality Range=1 to10

Table 1: Compression ratio with MSE, PSNR, and CR at different Qualities

Quality	Compression Ratio	PSNR	MSE
7.9	6.0269	31.7958	43.0030
8.0	6.0038	31.8559	42.4118
8.1	5.9806	31.9159	41.8299
8.2	5.9598	31.9759	41.2554
8.3	5.9384	32.0331	40.7164
8.4	5.9172	32.0890	40.1954
8.5	5.8950	32.1470	39.6619

Figure 2: Reconstructed image for quality 2, 4, 5 and 10 respectively from left to the right.

Virtually, the higher the quality of the image selected the better the visual appearance of the image, the poorer the compression.

A. Compression Ratio

The compression ratio is a measurement of the relative reduction in size of the image produced by the compression, it is defined as the ratio of the uncompressed file and the compressed file.

$$Compression\ Ratio = \frac{Uncompressed\ Size}{Compressed\ Size} \geq 1 \qquad (3)$$

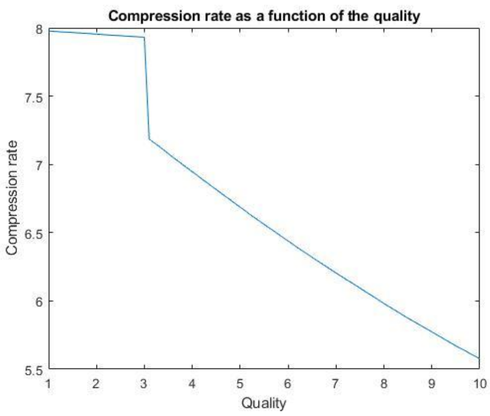

Figure 5: Compresion Ratio

The compression rate decreases if the quality required by the user increases as shown in Figure 5. This figure indicates that the compression ratio is constant in intervals which means that the sizes of the compressed images are the same in these intervals. The size of a file represents the number of bits contained in that file, and that the number of bits required depends on the quality.

B. JPEG comparison

The reconstructed image is compared to the source image using measurement tools such as the MSE and the PSNR. For a grayscale image of size N ×M, the MSE and PSNR are given using the following formulas Equation 4 and 5.

$$MSE = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}(p[i,j] - \bar{p}[i,j])^2 \quad (4)$$

PSNR=20log (Max)-20log (MSE) (5)

Where, $p[i,j]$ = Pixel at position (i, j) of the original image.
$\bar{p}[i,j]$= Pixel at position (i, j) of the reconstructed image.
Max= 2^{Bits}-1: Maximum possible pixel value of the source image.

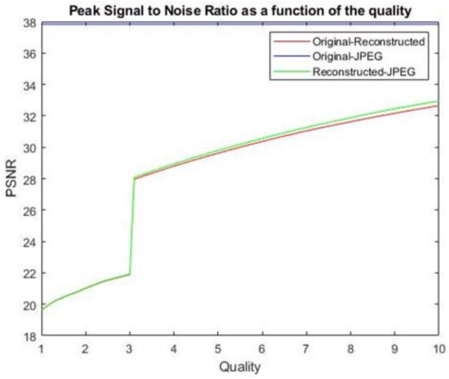

Figure 6: PSNR

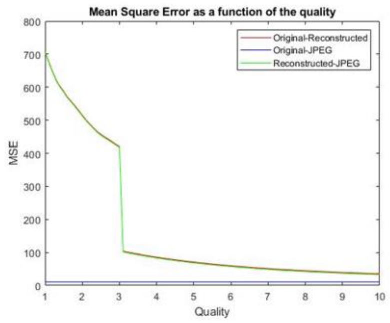

Figure 7: MSE

Figures 6 and 7 indicate that the algorithm offers a little lower performance than JPEG given its low MSE (high PSNR). The number of errors made using the proposed algorithm decreases as the quality increases, but a difference of nearly 20 dB exists between the PSNR of the reconstructed image and the original image.

C. CONCLUSSION

The experimental results show that DCT, quantization and Huffman strategy in image compression produces a little lower visual image quality at a minimum bit rates than JPEG compression. Result shows that high compression rates are achieved and visually negligible difference between compressed images and original images is maintained.

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