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JPEG Image Compression by Using DCT

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Abstract—Image compression is the application of data compression on digital images. The discrete cosine transform (DCT) is a technique for converting a signal into elementary frequency components. It is widely used in image compression. Here we develop some simple functions to compute the DCT and to compress images. The discrete cosine transform (DCT) is a mathematical function that transforms digital image data from the spatial domain to the frequency domain .In this paper the lossy compression techniques have been used, where data loss cannot affect the image clarity in this area. It is also used for reducing the redundancy that is nothing but avoiding the duplicate data. It also reduces the storage area to load an image.

Compression refers to reducing the quantity of data used to represent a file, image or video content without excessively reducing the quality of the original data. Image compression is the application of data compression on digital images. The main purpose of image compression is to reduce the redundancy and irrelevancy present in the image, so that it can be stored and transferred efficiently. The compressed image is represented by less number of bits compared to original. Hence, the required storage size will be reduced, consequently maximum images can be stored and it can transferred in faster way to save the time, transmission bandwidth. Depending on the compression techniques the image can be reconstructed with and without perceptual loss. In lossless compression, the reconstructed image after compression is numerically identical to the original image. In lossy compression scheme, the reconstructed image contains degradation relative to the original. Lossy technique causes image quality degradation in each compression or decompression step. In general, lossy techniques provide for greater compression ratios than lossless techniques i.e. Lossless compression gives good quality of compressed images, but yields only less compression whereas the lossy compression techniques lead to loss of data with higher compression ratio.

The inverse DCT would be performed using the subset of DCT coefficients. The error image (the difference between the original and reconstructed image) would be displayed.

Keywords—Image compression, DCT, QUANTIZER LPTCM

I. INTRODUCTION

Depending on the compression techniques the image can be reconstructed with and without perceptual loss. In lossless compression, the reconstructed image after compression is numerically identical to the original image. In lossy compression scheme, the reconstructed image contains degradation relative to the original. Lossy technique causes image quality degradation in each compression or decompression step. In general, lossy techniques provide for greater compression ratios than lossless techniques i.e. Lossless compression gives good quality of compressed images, but yields only less compression whereas the lossy compression techniques lead to loss of data with higher compression ratio[3],[4].

Image compression is very important for efficient transmission and storage of images. Demand for communication of multimedia data through the telecommunications network and accessing the multimedia data through Internet is growing explosively. With the use of digital cameras, requirements for storage, manipulation, and transfer of digital images has grown explosively.

These image files can be very large and can occupy a lot of memory .A gray scale image that is256 x 256 pixels has 65, 536 elements to store, and a typical 640 x 480 color image has nearly million. Downloading of these files from internet can be very time consuming task. Image data comprise of a significant portion of the multimedia data and they occupy the major portion of the communication bandwidth for multimedia communication. Therefore development of efficient techniques for image compression has become quite necessary. A common characteristic of most images is that the neighboring pixels are highly correlated and therefore contain highly redundant information.

The basic objective of image compression is to find an image representation in which pixels are less correlated. The two fundamental principles used in image compression are redundancy and irrelevancy. Redundancy removes redundancy from the signal source and irrelevancy omits pixel values which are not noticeable by human eye.

JPEG and JPEG 2000 are two important techniques used for image compression. Work on international standards for image compression started in the late 1970s with the CCITT (currently ITU-T) need to standardize binary image compression algorithms for Group 3facsimile communications [4],[5],[6]. Image compression standards bring about many benefits, such as:

(1)easier exchange of image files between different devices and applications;

(2) reuse of existing hardware and software for a wider array of products;

(3)existence of benchmarks and reference data sets for new and alternative developments.

1.1 Need of image compression

The needs for image compression becomes apparent when number of bits per image are computed resulting from typical sampling rates and quantization methods. For example, the amount of storage required for given images is

(i) a low resolution, TV quality, color video image which has 512 x 512 pixels/color, 8 bits/pixel, and 3 colors approximately consists of 6 x10^6 bits;

(ii) a 24 x 36 mm negative photograph scanned at 12x10^{-6}mm:3000 x 2000 pixels/color, 8 bits/pixel, and 3 colors nearly contains 144 x 10^6 bits;

(iii) a 14 x 17 inch radiograph scanned at 70 x 10^{-6}mm: 5000 x 6000 pixels, 12 bits/pixel nearly contains 360 x 10^6bits.

Thus storage of even a few images could cause a problem. As another example of the need for image compression, consider the transmission of low resolution 512 x 512 x 8 bits/pixel x 3-color video image over telephone lines. Using a 96000 bauds (bits/sec) modem, the transmission would take approximately 11 minutes for just a single image, which is unacceptable for most applications[4].

1.2 Principles Behind Compression

Image Compression addresses the problem of reducing the amount of data required to represent the digital image. We can achieve compression by removing of one or more of three basic data redundancies:

(1) Spatial Redundancy or correlation between neighboring pixels.

(2) Due to the correlation between different color planes or spectral bands, the Spectral redundancy is founded.

(3) Due to properties of the human visual system, the Psycho-visual redundancy is founded.

We find the spatial and spectral redundancies when certain spatial and spectral patterns between the pixels and the color components are common to each other and the psycho-visual redundancy produces from the fact that the human eye is insensitive to certain spatial frequencies.

Various techniques can be used to compress the images to reduce their storage sizes as well as using a smaller space. We can use two ways to categorize compression techniques.

1) Lossy Compression System

Lossy compression techniques are used in images where we can sacrifice some of the finer details in the image to save a little more bandwidth or storage space.

2) Lossless compression system

Lossless Compression System aims at reducing the bit rate of the compressed output without any distortion of the image. The bit-stream after decompression is identical to the original bit-stream.

Predictive coding

It is a lossless coding method, which means the value for every element in the decoded image and the original image is identical to Differential Pulse Code Modulation (DPCM).

Transform coding

Transform coding forms an integral part of compression techniques, the reversible linear
transform in transform coding aims at mapping the image into a set of coefficients and the resulting coefficients are then quantized and coded, the first attempts is the discrete cosine transform (DCT) domain. As compare to other methods of compression less memory is required to store images and that was explain in this paper.

II. METHODS FOR COMPRESSION

There are four methods for compression

1. Discrete Cosine Transform (DCT)
2. Discrete Wavelet Transform (DWT)
3. Vector Quantization (VQ)
4. Fractal Compression (FC)

1. Discrete Cosine Transform (DCT)

Discrete Cosine Transform (DCT) exploits cosine functions, it transform a signal from spatial representation into frequency domain. The DCT represents an image as a sum of sinusoids of varying magnitudes and frequencies. DCT has the property that, for a typical image most of the visually significant information about an image is concentrated in just few coefficients of DCT. After the computation of DCT coefficients, they are normalized according to a quantization table with different scales provided by the JPEG standard computed by psycho visual evidence. Selection of quantization table affects the entropy and compression ratio[7],[8]. The value of quantization is inversely proportional to quality of reconstructed image, better mean square error and better compression ratio. In a lossy compression technique, during a step called Quantization, the less important frequencies are discarded, then the most important frequencies that remain are used to retrieve the image in decomposition process. [4]. After quantization, quantized coefficients are rearranged in a

zigzag order for further compressed by an efficient lossy coding algorithm. DCT has many advantages:
(1). It has the ability to pack most information in fewest coefficients.
(2). It minimizes the block like appearance called blocking artifact that results when boundaries between sub-images become visible.

The image is divided into 8x8 pixel blocks and 2D- DCT is applied to each. Coarse quantization is applied to high spatial frequency components. Thus compressing the resulting data losslessly and stored. Spatial frequencies are scanned in zigzag pattern so that high frequencies will become mostly zero. Means Discrete cosine transform is a lossy compression algorithm[6]. That is discards those frequencies which do not affect the image as the human eye perceives it. For the two dimensional DCT the mathematical function is described as follows:

$$t(i,j) = c(i,j)\sum_{n=0}^{N-1}\sum_{m=0}^{N-1}\delta(m,n)cos\frac{\pi(2m+1)i}{2N}cos\frac{\pi(2n+1)j}{2N}$$

For the purpose of decoding, the Inverse Discrete Cosine Transform function is there, which is explained as follows:

$$t(i,j) = c(i,j)\sum_{n=0}^{N-1}\sum_{m=0}^{N-1}\delta(m,n)cos\frac{\pi(2m+1)i}{2N}cos\frac{\pi(2n+1)j}{2N}$$

Before we begin, it should be noted that the pixel values of a black and white image range from 0 to255 ,where pure black is represented by 0 and pure white by 255. Since image compress hundreds or even thousands of 8X8 block of pixels[6],[7].

Let's start with a block of image pixels values, this particular block was chosen from very upper-left hand corner of an image.

Block=

156	159	158	155	158	156	159	158
160	154	157	158	157	159	158	158
156	159	158	155	158	156	159	158
160	154	157	158	157	159	158	158
156	153	155	159	159	155	156	155
155	155	155	157	156	159	152	158
156	153	157	156	153	155	154	155
159	159	156	158	156	159	157	161

Because DCT is designed to work on pixels values ranging from -128 to 127, the original block is leaved off by subtracting 128 from each entry. This result in the following matrix

Block=

28	31	30	27	30	28	31	30
32	26	29	30	29	31	30	30
28	31	30	27	30	28	31	30
32	26	29	30	29	31	30	30
28	25	27	31	31	27	28	27
27	27	27	29	28	31	24	30
28	25	29	28	25	27	26	27
31	31	28	30	28	31	29	33

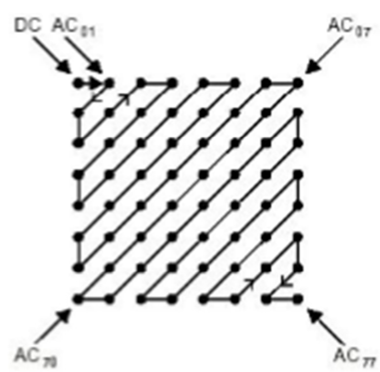
Now apply DCT to a block, this block matrix consist of 64 DCT coefficients, C_{ij} wherei & j range from 0 to 7. The top-left coefficient C_{oo} , correlates to low frequencies of original image block. As we move away from C_{oo} in all direction, DCT coefficient correlate to higher and higher frequencies of image block, where C_{77} corresponds to highest frequency[6]. After applying DCT matrix becomes as shown below

DCT_block =

230.875	-1.971	0.658	0.4709	2.375	1.0406	2.568	-0.497
3.820	-0.716	0.528	0.722	-1.9537	0.2029	-2.297	4.001
2.043	0.513	3.365	-1.440	-2.370	-1.585	-0.484	-0.654
-4.997	0.081	-3.167	-0.462	0.911	-0.909	0.534	-0.288
3.375	-0.434	0.3218	0.620	0.875	0.289	-2.162	0.5289
-2.079	0.922	1.129	-1.426	-2.559	0.048	0.376	1.4228
1.994	-0.728	1.015	-1.386	-2.13	-5.438	-2.115	-0.753
-2.857	-1.267	0.983	-2.043	-1.271	-0.411	-3.804	3.130

1.1 ZIGZAG SCANNING

In the "zig-zag" sequence, firstly it encodes the coefficients with lower frequencies (typically with higher values) and then the higher frequencies (typically zero or almost zero). The result is an extended sequence of similar data bytes, permitting efficient entropy encoding



DCT_Z =
Columns 1 through 9
230.8750 -1.9711 3.8203 2.0439 -0.7165 0.6581 0.4709 0.5280 0.5134
Columns 10 through 18
-4.9979 3.3750 0.0819 3.3650 0.7221 2.3750 1.0406 -1.9537 -1.4406
Columns 19 through 27
-3.1677 -0.4348 -2.0790 1.9947 0.9224 0.3218 -0.4627 -2.3705 0.2029
Columns 28 through 36
2.5687 -0.4977 -2.2978 -1.5856 0.9110 0.6203 1.1297 -0.7280 -2.8577
Columns 37 through 45
0.9839 1.0152 -1.4267 0.8750 -0.9090 -0.4848 4.0017 -0.6546 0.5341
Columns 46 through 54
0.2899 -2.5590 -1.3862 -1.2675 -2.0439 -2.1300 0.0485 -2.1628 -0.2885
Columns 55 through 63
0.5289 0.3766 -5.4382 -1.2717 -0.4118 -2.1150 1.4228 -0.7537 -3.8042
Column 64
3.1307

1.2 QUANTIZATION

DCT-based image compression relies on two techniques to reduce the data required to represent the image. The first is quantization of the image's DCT coefficients; the second is entropy coding of the quantized coefficients. Quantization is the process of reducing the number of possible values of a quantity, thereby reducing the number of bits needed to represent it. We will develop functions to quantize images and to calculate the level of compression provided by different degrees of quantization.

Q_vec =
Columns 1 through 18
231 3 3 3 3 3 3 3 0 0 3 0 0 3 3 3 3 3
Columns 19 through 36
3 0 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
Columns 37 through 54
3 3 0 3 3 3 3 3 3 3 3 3 3 3 3 4 3 3
Columns 55 through 64
3 3 0 3 3 3 3 3 3 3

2. Discrete Wavelet Transform (DWT)

Like DCT, Discrete Wavelet Transform mathematically transforms an image into frequency components. The low pass filter performs an averaging/blurring operation, and the high-pass filter performs a differencing operation .

3. Vector Quantization (VQ)

Vector quantization is a lossy compression that looks at an array of data, instead of individual values. It can then generalize what it sees, compressing redundant data, while at the same time retaining the desired object or data stream's original intent.

4. Fractal Compressions (FC)

Fractal compression is a form of VQ and is also a lossy compression. Compression is performed by locating self-similar sections of an image, then using a fractal algorithm to generate the sections.

III. Conclusion

Image compression is used for managing images in digital format. In this paper the lossy compression techniques have been used, where data loss cannot affect the image clarity in this area.

This paper has been focused on the fast and efficient image compression and decompression using Discrete Cosine Transform. We also briefly introduced the principles behind the Digital Image compression and various image compression techniques.

In this paper first divide image into 8x8 block and then apply DCT to the first block only. The result of every step was display above.

IV. Future Work

In the future work we will design a Laplacian Transparent Composite Model (LPTCM) for image compression. We also measure PSNR of different images and compare result of both the methods.

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