Image Compression and Effect of Quantizing Different Frequency Components

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Abstract

Image data compression is a very important problem for many emerging applications in the fields of visual communication and communication networks. Lossy image compression using transform coding provides better compression with negligible loss of visual quality and is adopted by many Image standards including JPEG. In lossy image compression system, quantization plays a main role in providing tradeoff between image quality and compression rate. This paper tells about quantizing various frequency components and their effect on the image quality and the compression rate.

Index terms: Image compression, Discrete Cosine Transform, Quantization, Entropy Coding.

Introduction

Image compression [1, 2] is of significant use in different applications working with images. Digital transmission of uncompressed images (stored in Bitmap format) on low bandwidth communication channels is very time consuming, e.g., for the transmission of a color image having image dimension of 256 x 256 picture elements (pixels), and each pixel coded with 24 bits, about 24 sec total transmission time is needed if the channel rate is 64 Kbits/s, and the lossy compressed image requires about 3 sec total transmission time on the same channel. The lossy compressed images require 5-30 less transmission time and less storage space and the exact value depends on the image. Image compression is achieved by removing coding redundancy (using variable length coding techniques) and psycho visual redundancy (neglecting less perceptible information) [1].

Hence many image compression systems use lossy compression techniques to achieve greater compression and many standards are developed for compressing the image using these techniques, e.g., JPEG [3, 4].

Lossy Image Compression

In a lossy compression system the image is converted from one color representation to other so that different components of the image can use different type of compression techniques based on the human perception.

Separating the color and brightness information aids wells as human have less perception to color changes than brightness changes. YCbCr [2, 5] color representation separates color component (Cb, Cr) and brightness (Y) component from the image and is typically used for compressing color images. Since color component changes are less perceptible than brightness components color components can be sub sampled to achieve greater compression without losing much visual information.

The frequency domain is a better representation for the data because it makes it possible to separate information that isn't very important to human perception. The human eye is not very sensitive to high frequency changes especially in photographic images, so the high frequency data can, to some extent, be discarded without perceptual loss of information. The spatial data is converted to frequency domain using Discrete Cosine Transform (DCT) [6] as it exhibits very good energy compaction and decorrelation properties. It has been shown that the DCT is asymptotic approximations to the optimal Karhunen-Loeve transform [2], when a first-order Markov model can describe the statistical properties of the image.

The DCT can be computed using Fast DCT [7] (or FFT), which exploit the symmetric properties of the transform. Because of the advantages Joint Photography Experts Group (JPEG) [2] has recommended DCT for compression of still images. The DCT is a reversible process that theoretically does not yield error. Due to floating point arithmetic some round off error occur when converting the spatial data to frequency data. Greater compression can be achieved by quantizing the frequency components that are less perceptible to human eye. That is giving more importance to the frequency components, which are more perceptible to human eye, and less importance to the frequency components less perceptible to human eye can increase compression rate.

The image is sub divided into sub images of 8x8 block size and each block is transformed into frequency domain for further processing. The block size of 8x8 is chosen as it provides a good tradeoff between computation time and error compared to other block sizes. Since sensitivity of eye decreases with increasing frequency changes, most of the high frequency components can be neglected with losing much visual information.

Quantization quantizes the frequency components based on the perceptual importance. Quantization though is a lossy process is intentionally performed to achieve greater compression. This paper considers the effect of quantizing different frequency components and the visual clarity and the compression performance. The quantized data is arranged in zigzag fashion in which the quantized data is arrange in increasing order of the frequency components as it aids well in entropy coding. The reordered data is entropy coded to remove Coding Redundancy using variable length coding techniques.

Huffman coding and Run Length Encoding techniques are commonly used. The standard file format requires storing the entropy coded data and the tables used for coding (Huffman and Quantization tables) in the standard format. JPEG file format uses different marker segments to store the coded information so that the image can be decoded using the available information present in the JPEG file.

Effect of quantization

The quantization is main process, which provides a trade off between image quality and the compression ratio. Human eye has different level of perception to different frequency components. So certain frequency components though neglected completely the image quality perceptually does not change. Hence proper selection of quantization table enhances image compression without much loss of visual information. Since luminance and chrominance components have different perceptual response separate tables can be used to achieve greater compression. JPEG standard defined 2 quantization tables (1 for Y and 1 for Cb, Cr) based on the perception of human eye. This paper shows the results of quantizing different frequency components and error and compression rate achieved. Different types of images are tested with different quantization tables and the results are tabulated.

Theoretically loss less compression can be obtained by selecting quantization tables (QT), which have all the quantization values, set, to 1 but achieves less compression. Due to rounding off DCT coefficients some quantization error occurs which cannot be perceived by human eye (_1.qt). The QT with low quantization values for smaller frequency coefficients and with increasing quantization values for high frequency coefficients provides good compression ratio and better visual quality. QT, which considers 75% of DCT coefficients with increasing frequency (_1110), provides quality image and compression rate close to theoretical loss less compressed image. QT, which considers 50% of DCT coefficients with increasing frequency (_upt1), provides good quality image and compression rate slightly better than theoretical loss less compressed image.

QT, which has its quantization values doubling with frequency components in horizontal direction (_right2), provides image quality close to _upt1 and much better compression rate. QT which considers 50% of horizontal (_1100) or vertical (_1010) frequency components with increasing frequency also provide similar compression rate as upt1 but the image quality is not that much better than _upt1.

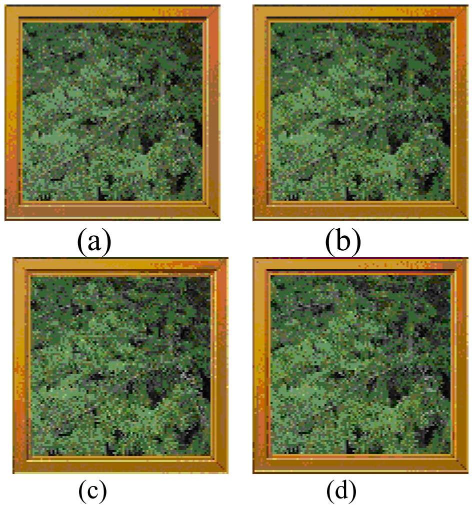

Fig 1. Forest Image quantized with different quantization values. (a). QT which has bottom right 4x4 block quantization values equal to 255 and other values equal to 1 (_1110). (b). QT, which has quantization value of 1 for 8x8 upper triangle part and other values, are 255 (_upt1). (c) QT having JPEG defined Quantization table values (_j). (d) QT has quantization value, which is power of 2 moving from left to right and also from top to bottom of 8x8 block (_22).

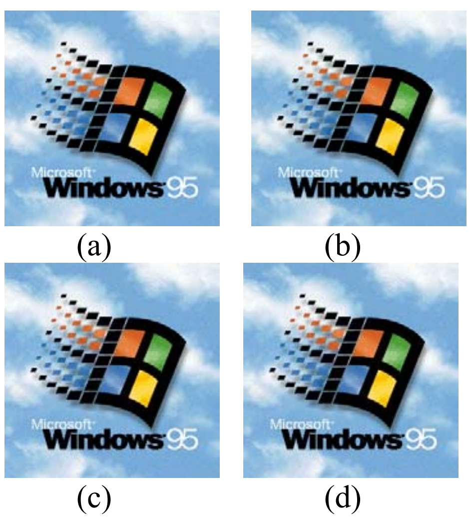

Fig 2. Windows Image quantized with different quantization values. (a). QT which has bottom right 4x4 block quantization values equal to 255 and other values equal to 1 (_1110). (b). QT, which has quantization value of 1 for 8x8 upper triangle part and other values, are 255 (_upt1). (c) QT having JPEG defined Quantization table values (_j). (d) QT has quantization value, which is power of 2 moving from left to right and also from top to bottom of 8x8 block (_22).

QT which has its quantization values doubling with increase in horizontal and vertical direction (_22) of frequency provides better image quality than JPEG defined QT table (_j) but need slightly more memory space. The performance of the compression and quality of the image greatly decreases if high frequency components are considered and low frequency components are ignored.

Table 1. Mean Square Error value of pixels and Compressed JPEG file size for various Quantization values of Win95.bmp image file

MSE	SIZE (KB)	FILE TYPE
3089840	74.64	w_1.bmp
5157425	63.2	w_1110.bmp
8467790	48.4	w_upt1.bmp
10464755	32.52	w_right2.bmp
16217823	47.73	w_1100.bmp
17011060	46.5	w_1010.bmp
20342924	13.7	w_22.bmp
24516788	8.21	w_j.bmp
95653526	27.48	w_left2.bmp
280173757	1.24	w_255.bmp

Table 2. Mean Square Error value of pixels and Compressed JPEG file size for various Quantization values of Forest.bmp image file

MSE	SIZE (KB)	FILE TYPE
8498249	88.59	f_1.bmp
18278209	73.12	f_1110.bmp
27064697	41.18	f_right2.bmp
27440506	54.72	f_upt1.bmp
41835072	52.24	f_1010.bmp
45266511	53.23	f_1100.bmp
51929058	16.47	f_22.bmp
55405805	10.86	f_j.bmp
234026588	38.02	f_left2.bmp
512296477	1.02	f_255.bmp

QT which considers high frequency components and neglects low frequency components (_left2) typically have nearly 10 times more error compared to QT which prefers low frequency over high frequency (_right2) for the same compression rate. QT with high quantization value for all the frequency (_255) coefficients yield good compression but most of the image quality is lost so cannot be used for image compression. It is observed from the results that we can select a quantization table based on the required quality and compression rate.

Results

The results of using different quantization tables are shown in table 1 and 2. The Mean Square Error (MSE) and the compressed image size for different quantization tables are considered to show the effect of quantizing different frequency components. The image Forest.BMP and Win95.BMP are the image results shown and each image is of different type. The uncompressed image size in bitmap format is 196 KB. The results show the effect of quantization on different frequency components based on the error and the compression rate. From the results it is observed that the quantization tables which quantizes frequency components with increasing frequency achieves better compression and less error.

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