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Effect of Quantisation on Compression ratio and time to Decode JPEG Image

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Abstract: Image Compression addresses the problem of reducing the amount of data required to represent the digital image. Compression is achieved by the removal of one or more of three basic data redundancies Coding redundancy, which is present when less than optimal code words are used; Inter pixel redundancy, which results from correlations between the pixels of an image & psycho visual redundancy which is due to data that is ignored by the human visual system. Huffman codes contain the smallest possible number of code symbols per source symbol) subject to the constraint that the source symbols are coded one at a time. So, Huffman coding when combined with technique of reducing the image redundancies using Discrete Cosine Transform helps in compressing the image data to a very good extent. The DC relocates the highest energies to the upper left corner of the image. The lesser energy or information is relocated into other areas. From the simulation of the proposed algorithm, it can be concluded that classic DCT with Coarse quantization gives best output and number of coefficient should be around half of the net coefficient to reconstruct the image.

Keywords: DCT (discrete cosine transform), DWT (discrete wavelet transform).

1. Introduction

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. It also reduces the number of bits required to store and/or transmit digital media. To compress something means that you have a piece of data and you decrease its size. JPEG is the best choice for digitized photographs. The Joint Photographic Expert Group (JPEG) system, based on the Discrete Cosine Transform (DCT), has been the most widely used compression method [1][2]. In DCT image data are divided up into n*m number of block. DCT converts the spatial image representation into a frequency map: the average value in the block is represented by the low-order term, strength and more rapid changes across the width or height of the block represented by high order terms. DCT is simple when JPEG used, for higher compression ratio the noticeable blocking artifacts across the block boundaries cannot be neglected. The DCT is fast. It can be quickly calculated and is best for images with smooth edges.

Discrete wavelet transform (DWT) has gained widespread acceptance in signal processing and image compression. Huffman coding is a statistical lossless data compression technique. Huffman coding is based on the frequency of pixel in images. It helps to represent a string of symbols with lesser number of bits. In this lossless compression shorter codes are assigned to the most frequently used symbols, and longer codes to the symbols which appear less frequently in the string. This algorithm is an optimal compression algorithm when only the frequencies of individual letters are used to compress the data. Therefore, when Huffman coding combined with the technique of reducing image redundancies using Discrete Cosine Transform (DCT), helps in compressing the image data to a better level. The Discrete Cosine Transform (DCT) is an example of transform coding. The DCT coefficients are all real numbers unlike the Fourier Transform. The Inverse Discrete Cosine Transform (IDCT) can be used to retrieve the image from its transform representation. The one-dimensional DCT is useful in processing speech waveforms. The two dimensional (2D) signals useful in processing images, for compression coding we need a 2D version of the DCT data, for optimal performance. JPEG is a commonly used standard method of compression for photographic images. The name JPEG stands for Joint Photographic Experts Group, the name of the committee who created the standard. JPEG provides for lossy compression of images. Lossy compression means that some data is lost when it is decompressed. Lossless compression means that when the data is decompressed, the result is a bit-for-bit perfect match with the original one.

The wavelet decomposition method uses two types of filters, i.e low pass filter and high pass filter. In this decomposition ,a Discrete wavelet transform (DWT) image is split into several sub bands(LL,LH,HL,HH); only LL sub band is decomposed further, because it has low frequency and noise compare to other sub band levels[3]. The basic steps for a wavelet based image compression are as shown in figure 1 below [4]:

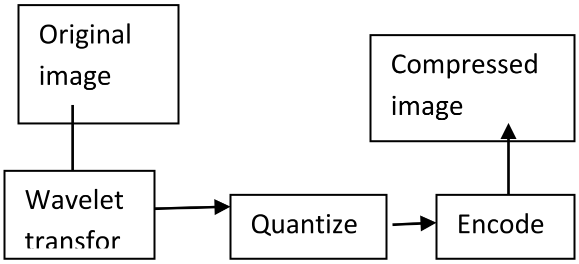

Figure 1 wavelet based image compression

The basic steps for a wavelet based image de-compression are as shown in figure 2 below

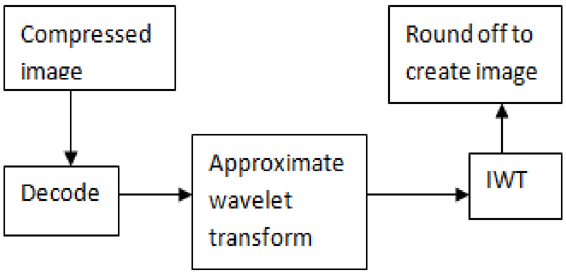

Figure 2 wavelet based de-compression

2. Today's Scenario

The International Standards Organization (ISO) has proposed the JPEG standard for image compression. Each color component of still image is treated as a separate gray scale picture by JPEG. Although JPEG allows any color component separation, images are usually separated into Red, Green, and Blue (RGB) or Luminance (Y), with Blue and Red color differences (U = B – Y, V = R – Y). Separation into YUV color components allows the algorithm to take the advantages of human eyes' lower sensitivity to color information. For quantization, JPEG uses quantization matrices. JPEG allows a different quantization matrix to be specified for each color component [5]. Though the JPEG provides good results previously, it is not perfectly suited for modern multimedia applications because of blocking artifacts.

Wavelet theory and its application in image compression had been well developed over the past decade. The field of wavelets is still sufficiently new and further advancements will continue to be reported in many areas. Many authors have contributed to the field to make it what it is today, with the most well known pioneer probably being Ingrid Daubechies. Other researchers whose contribution directly influences this work include Stephane Mallat for the pyramid filtering algorithm, and the team of R. R. Coifman, Y. Meyer, and M. V. Wickerhauser for their introduction of wavelet packet [6].

Further research has been done on still image compression and JPEG-2000 standard is established in 1992 and work on JPEG-2000 for coding of still images has been completed at end of year 2000. The JPEG-2000 standard employs wavelet for compression due to its merits in terms of scalability, localization and energy concentration [6, 7]. It also provides the user with many options to choose to achieve further compression. JPEG-2000 standard supports decomposition of all the sub-bands at each level and hence requires full decomposition at a certain level. The compressed images look slightly washed-out, with less brilliant color. This problem appears to be worse in JPEG than in JPEG-2000 [8]. Both JPEG-2000 and JPEG operate in spectral domain, trying to represent the image as a sum of smooth oscillating waves. JPEG-2000 suffers from ringing and blurring artifacts. [8]

Most of the researchers have worked on this problem and have suggested the different techniques that minimize the said problem against the compromise for compression ratio.

3. Wavelet and Wavelet Packet

In order to represent complex signals efficiently, a basis function should be localized in both time and frequency domains. The wavelet function is localized in time domain as well as in frequency domain, and it is a function of variable parameters.

The wavelet decomposes the image, and generates four different horizontal frequencies and vertical frequencies outputs. These outputs are referred as approximation, horizontal detail, vertical detail, and diagonal detail. The approximation contains low frequency horizontal and vertical components of the image. The decomposition procedure is repeated on the approximation sub-band to generate the next level of the decomposition, and so on. It is leading to well known pyramidal decomposition tree. Wavelets with many vanishing yield sparse decomposition of piecewise smooth surface; therefore they provide a very appropriate tool to compactly code smooth images. Wavelets however, are ill suited to represent oscillatory patterns [10, 11]. A special from a texture, oscillating

variations, rapid variations in the intensity can only be described by the small-scale wavelet coefficients. Unfortunately, these small-scale coefficients carry very little energy, and are often quantized to zero even at high bit rate.
The weakness of wavelet transform is overcome by new transform method, which is based on the wavelet transform and known as wavelet packets. Wavelet packets are better able to represent the high frequency information [9].
Wavelet packets represent a generalization of multi resolution decomposition. In the wavelet packets decomposition, the recursive procedure is applied to the coarse scale approximation along with horizontal detail, vertical detail, and diagonal detail, which leads to a complete binary tree.

4. Algorithm

The basic algorithm for the compression of an image corresponding to JPEG with Fast and Classic DCT, and varying quantization is presented below, which helps to clears the view of calculation and compression technique.

I. Read the image file using function imread() which returns the intensity vector matrix in uint8 format
II. The image is then undergo block processing of size [8 8].
III. Firstly the type of DCT is selected and then number of DCT coefficients to be transmitted is selected.
IV. The higher energy coefficients are selected for encoding the block and lower energy coefficients are skipped.
V. Coefficients are quantized with a particular identified quantization matrix.
VI. The coefficients after quantization are traced to convert it in a row matrix in a zig-zag fashion.
VII. Now an entropy encoding is used to transmit this vector. The run-length coding is used to do so.
VIII. Now time count starts for decoding process.
IX. The decoding process used just opposite to the encoding.
X. Different variation of quantization and DCT process resulted images are decoded.
XI. Time to elapse the process, compression ratio is also calculated.

$$\text{compression ratio} = \frac{\text{actual size of image in bits}}{\text{compressed size of image in bits}}$$

XII. End the process.

5. Result

The simulation result of given algorithm is presented in Figure 3 and table 1, which helps to draw the conclusion between different parameter resulted from simulation output.

5.1 Effect of number of coefficient on time to Decode:

It can be observed from all the simulated result that compression ratio is independent of no. of coefficient used to recover the image only thing that gets effected is time and as the no. of coefficient increase the time of decoding decreases.

5.2 Effect of quantization on Compression ratio and time to Decode:

It can be observed that as coarse quantization results higher compression ratio and less time to reconstruct the image than fine quantization for same number of coefficient.

5.3 Effect of DCT Type on Compression Ratio and Time to decode:

It can be observed from the table 1 that classic DCT take less to reconstruct the image than Fast DCT.

6. Conclusion

Image compression is of prime importance in real time applications like video conferencing where data are transmitted through a channel. Using JPEG standard DCT is used for mapping which reduces the inter pixel redundancies followed by quantization which reduces the psycho visual redundancies then coding redundancy is reduced by the use of optimal code word having minimum average length. From the above relation between input and output parameters, it can be concluded that classic DCT with Coarse quantization gives best output and number of coefficient should be around half of the net coefficient to reconstruct the image.

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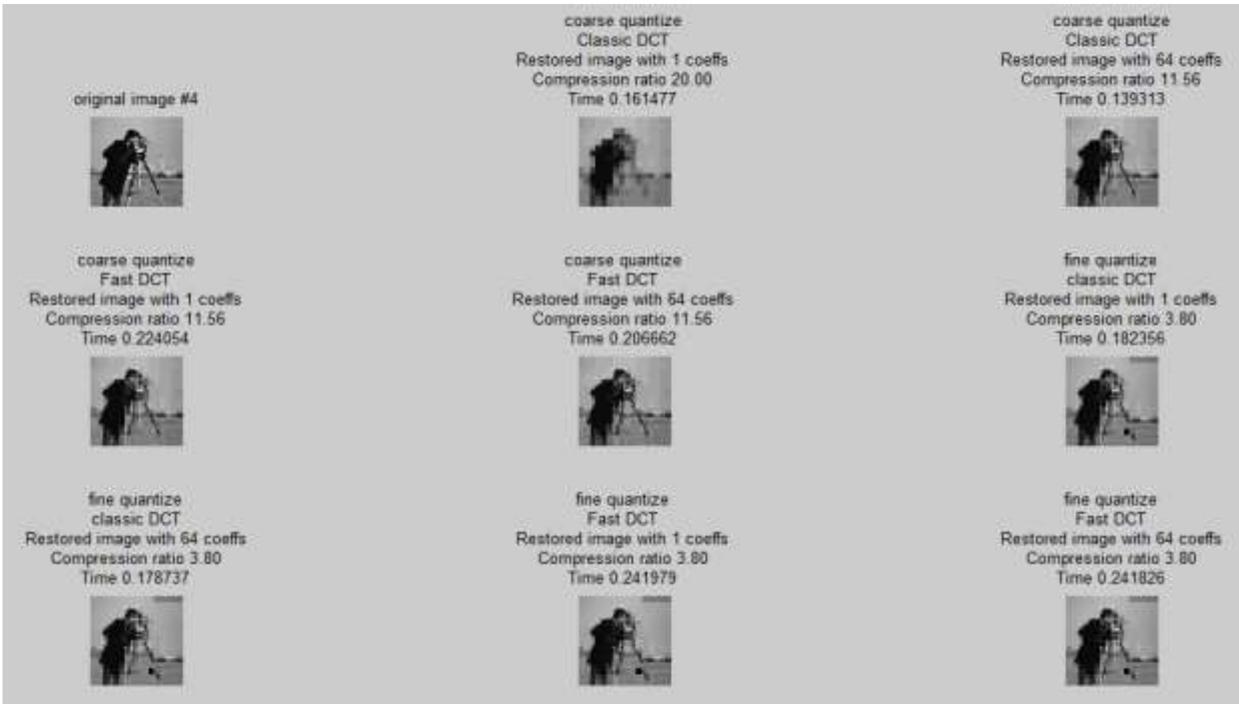

Figure 4.3 simulation result of variation in Quantization and DCT type

Table 1 Effect of quantization and DCT type on compression ratio and time to decode image

	Quantize					
	Coarse		Fine			
Compression ratio	**11.56**	**20**	**3.80**	**3.80**	**1**	**Restored Coefficient**
Time	**0.224054**	**0.161477**	**0.241979**	**0.182356**		
Compression ratio	**11.56**	**11.56**	**3.80**	**3.80**	**64**	
Time	**0.206662**	**0.139313**	**0.241826**	**0.178737**		
	Fast	**classic**	**Fast**	**Classic**		
	DCT Type					