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Performance Analysis of Chrominance Red & Chrominance Blue in JPEG

Mamta Garg

***Abstract*—**While compressing text files is useful, compressing still image files is almost a necessity. A typical image takes up much more storage than a typical text message and without compression images would be extremely clumsy to store and distribute. The amount of information required to store pictures on modern computers is quite large in relation to the amount of bandwidth commonly available to transmit them over the Internet and applications. Image compression addresses the problem of reducing the amount of data required to represent a digital image. Performance of any image compression method can be evaluated by measuring the root-mean-square-error & peak signal to noise ratio. The method of image compression that will be analyzed in this paper is based on the lossy JPEG image compression technique, the most popular compression technique for color images. JPEG compression is able to greatly reduce file size with minimal image degradation by throwing away the least "important" information. In JPEG, both color components are downsampled simultaneously, but in this paper we will compare the results when the compression is done by downsampling the single chroma part. In this paper we will demonstrate more compression ratio is achieved when the chrominance blue is downsampled as compared to downsampling the chrominance red in JPEG compression. But the peak signal to noise ratio is more when the chrominance red is downsampled as compared to downsampling the chrominance blue in JPEG compression. In particular we will use the hats.jpg as a demonstration of JPEG compression using low pass filter and demonstrate that the image is compressed with barely any visual differences with both methods.

***Keywords*—**JPEG, Discrete Cosine Transform, Quantization, Color Space Conversion, Image Compression, Peak Signal to Noise Ratio & Compression Ratio.

I. Introduction

TODAY, compression has made a great impact on the storing of large volume of image data. Even hardware and software for compression and decompression are increasingly being made part of a computer platform. Take for example, Kay and Levine (1995, pg. 22) state that "the System 7 operating system of Macintosh computers, now includes a compression engine offering several types of compression and decompression." [1]. Most important question is "How can we represent information in a compact, efficient way?"[2].

Since the mid-80s, members from both the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) have been working together to establish a joint international standard for the compression of grayscale and color still images. This effort has been known as JPEG, the Joint Photographic Experts Group. JPEG became a Draft International Standard (DIS) in 1991 and an International Standard (IS) in 1992 [3-6].

It achieves compression by quantizing the discrete cosine transform (DCT) coefficients of the image's three color planes. However, the various settings used during JPEG compression and decompression are not standardized [7]. The following JPEG settings can be chosen by the user such as an imaging device: (1) the color space used to independently compress the image's three color planes; (2) the sub sampling employed on each color plane during compression and interpolation used during decompression; and (3) the quantization table used to compress each color plane.

The JPEG compression principle is the use of controllable losses to reach high compression rates [8]. In this context, the information is transformed to the frequency domain through DCT. Since neighbor pixels in an image have high likelihood of showing small variations in color, the DCT output will group the higher amplitudes in the lower spatial frequencies [9]. Then, the higher spatial frequencies can be discarded, generating a high compression rate and a small perceptible loss in the image quality. The JPEG compression is recommended for photographic images, since drawing images are richer in high frequency areas that are distorted with the application of the JPEG compression [10].

II. JPEG Overview

JPEG compression is able to greatly reduce file size with minimal image degradation by throwing away the least "important" information. Because it actually eliminates information, it is considered a "lossy" compression technique. That is, the final image resulting from the compression technique is not exactly the original image. In this section we will review JPEG compression process.

A. Conversion

In this phase pixel data is converted from the RGB to the YCBCR color space and down sampling may be performed. The human visual system is less sensitive to color than to luminance. In the RGB color space the three colors are equally important and so are usually all stored at the same resolution .but it is also possible to represent a color image more

Mamta Garg is with the Govt. Polytechnic College for Girls, Ropar, India (corresponding author to provide phone: 9855427557; e-mail: mamta2050@yahoo.co.in).

efficiently by separating the luminance from the color information and representing luma with a higher resolution than color.

The luminance information can be coded using higher bandwidth than the chrominance information [11]. So images can be converted from RGB to 3-component known as YCbCr with Y representing the luminance value and Cb and Cr representing the blueness and redness of the image respectively.

B. Sampling

In order to convert a photograph to a digital image, the image is scanned and each component is sampled at regular intervals. JPEG allows individual components to be sampled at different frequencies.

Sampling frequencies allow the image to be represented by numbers whilst varying the amount of information contributed by each component. Because Y has the greatest influence upon the image, the Cr and Cb components are down-sampled to reduce the amount of information they offer. Down-sampling is a simple method employed to reduce the compresses file size.

C. Discrete Cosine Transform (DCT)

It is widely used in image compression. Developed by Ahmed, Natarajan, and Rao [12], the DCT is a close relative of the discrete Fourier transform (DFT). Its application to image compression was pioneered by Chen and Pratt [13]. Two variants are used by the JPEG standard: the Forward DCT (usually simply referred to as the DCT) is used to compress the images and the Inverse DCT (IDCT) is used decompress the image.

The fundamental idea behind JPEG and for that matter any picture compression is that one can take the values stored in a picture matrix and transform those numbers from one basis to another, where the new basis stores relevant information in a more compact form.

In JPEG compression ,image is broken into 8*8 blocks, Then these 8×8 'mini-matrix' blocks are put through the DCT, where the lower frequencies, or gradual changes in luminosity are pushed toward the upper-left of the 8×8 matrix. While the DCT is the key to JPEG compression, it does not do any of the compression itself; it merely gets the image in the correct form so that the essential parts of the image are apparent. The important thing is the data has been organized in terms of importance. The human eye has more difficulty discriminating between higher frequencies than low and most computer data is relatively low frequency. Low frequency data carries more important information than the higher frequencies.

D. Quantization

The human eye is good at seeing small differences in brightness over a relatively large area, but not so good at distinguishing the exact strength of a high frequency brightness variation. This fact allows one to get away with greatly reducing the amount of information in the high frequency components. This is done by simply dividing each component in the frequency domain by a constant for that component, and then rounding to the nearest integer.

This is the main lossy operation in the whole process. As a result of this, it is typically the case that many of the higher frequency components are rounded to zero, and many of the rest become small positive or negative numbers, which take many fewer bits to store.

During Quantization every element in the 8x8 FDCT matrix is divided by a corresponding element in a quantization matrix according to the formula. JPEG standard defines two types of quantization tables.

The goal of quantization is to reduce most of the less important high frequency coefficients to zero, the more zeros we can generate the better the image will compress. it allows the user to customize the level of compression at runtime to fine tune the quality cum compression ratio.

If the user wants better quality at the price of compression he can lower the values in the Q matrix. If he wants higher compression with less image quality he can raise the values in the matrix.

E. Zig-zag Ordering

Before actual entropy is performed to the quantized DCT coefficients, the coefficients are rearranged into a one dimensional array using a zig-zag pattern by the code model, with the lowest frequency first and highest frequency last. The zig-zag pattern is used to increase the consecutive runs of zeros for RLE. During this stage the quantized DC coefficient is treated separately from the AC coefficient.

F. Run-length Encoding

The simplest form of compression technique which is widely supported by most bitmap file formats such as TIFF, BMP, and PCX. RLE performs compression regardless of the type of information stored, but the content of the information does affect its efficiency in compressing the information.

G. Huffman Encoding

Huffman encoding works by substituting more efficient codes for data and the codes are then stored as a conversion table and passed to the decoder before the decoding process takes place.

This approach was first introduced by David Huffman in 1952 for text files and has spawned many variations. Even CCITT (International Telegraph and Telephone Consultative Committee) 1 dimensional encoding used for bi-level, black and white image data telecommunications is based on Huffman encoding.

III. JPEG Compression By Downsampling the Chrominance Blue

The representation of image in RGB color space is converted to YCBCR color space where Y represents the luminance value & Cb & Cr represents the color part of an image. Chrominance blue is downsampled by a factor 2 or 4.

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After that each image component is divided into 8*8 block of elements. Then Discrete Cosine Transform is applied to each of the block of three image componnents & after that quantization is applied to each image component. During this step each element of transformed block is divided by the corresponding element of quantization table. During quantization information in the high frequency component is greatly reduced & so this is the main lossy step in the whole process.

After that the coefficients are rearranged into a one dimensional array using a zig-zag pattern. Then each image component is further compressed by lossless algorithm like run length encoding & variant of huffman encoding. After then image is compressed image is in the form of structure.

Fig. 1 represents the original 'hats.jpg' image, while the Fig. 2 represents reconstructed image when chrominance blue is downsampled by the factor 2. Fig. 2 also shows that compression ratio 26.5066 is achieved with the peak signal to noise ratio is 32.9300 & the root mean square error is 5.7549.

Fig. 1 Original Image of 'hats.jpg'

Fig. 2 Reconstructed Image in case of downsampling the Cb by 2

IV. JPEG Compression by Downsampling the Chrominance Red

The representation of image in RGB color space is converted to YCBCR color space where Y represents the luminance value & Cb & Cr represents the color part of an image. Chrominance red is downsampled by a factor 2 or 4.

After that each image component is divided into 8*8 block of elements. Then Discrete Cosine Transform is applied to each of the block of three image componnents & after that quantization is applied to each image component. During this step each element of transformed block is divided by the corresponding element of quantization table. During quantization information in the high frequency component is greatly reduced & so this is the main lossy step in the whole process.

After that the coefficients are rearranged into a one dimensional array using a zig-zag pattern. Then each image component is further compressed by lossless algorithm like run length encoding & variant of huffman encoding. After then image is compressed image is in the form of structure.

Fig. 3 represents the reconstructed image when chrominance red is downsampled by the factor 2. Fig. 3 also indicates that compression ratio of 25.5911 is achieved with the peak signal to noise ratio is 33.1689 & the root mean square error is 5.5988.

Fig. 3 Reconstructed Inage in case of downsampling the Cr by 2

V. Results & Discussions

PSNR measures are estimates of the quality of a reconstructed image compared with the original image. The actual value of PSNR is not meaningful, but the comparison between the two values of different reconstructed images gives a measure of quality.

The compression efficiency is measured using the compression ratio. The quality of an uncompressed image is measured using the Peak Signal to Noise Ratio (PSNR).

The PSNR is computed based on the Mean Square Error (MSE). The formulas (2) and (3) define the PSNR and MSE, respectively. In formulas (2) and (3), M and N refer to the number of pixels in a row and a column respectively.

$$PSNR = 10\log 10\left(\frac{255^2}{MSE}\right) \tag{2}$$

$$MSE = \frac{1}{MN}\sum_{x=0}^{M}\sum_{y=0}^{N}(I(x,y) - \hat{I}(x,y))^2 \tag{3}$$

The difference between the compressed image and the original image was also calculated. The illustration was generated by the Image Processing Toolbox of MATLAB &. Normalization Array of both Luminance & Chrominance is multiplied by the factors 1.5, 2, 2.5, 3, 3.5 & 4 respectively.

These results are also plotted in to show the changes for the RMSE as compression ratio changes. Fig. 4 shows that compression ratio is more when the compression is done by downsampling the chrominance blue, but root mean square error is less in the case when compression is done in case of chrominance red.

Fig. 5 indicates that more peak signal to noise ratio is achieved in case of image is compressed by downsampling the chrominance red. From these graphs, it can be concluded that more compression is achieved when the image is compressed by downsampling the chrominance blue and more quality is obtained when the image is compressed by downsampling the chrominance red.

So to obtain more compression, compress the image by downsampling the chrominance blue only & to obtain more quality and less value of root mean square error, compress the image by downsampling the chrominance red only.

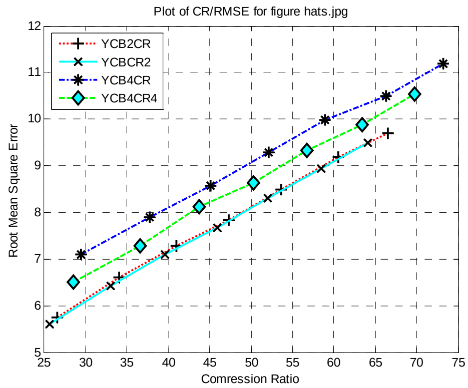

Fig. 4 Comparison of RMSE values against Compression Ratio

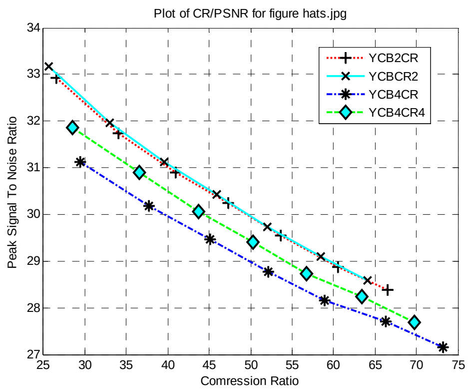

Fig. 5 Comparison of PSNR values against Compression Ratio

VI. Conclusion & Future Work

It was discussed in the earlier parts of the paper that the JPEG lossy compression scheme is one of the most popular and versatile compression schemes in widespread use. It's ability to attain considerable size reductions with minimal visual impact with relative light computational requirements and the ability to fine tune the compression level to suit the image at hand has made it the standard for continuous-tone still images. It is demonstrated that more quality of image is achieved, when the compression is done by downsampling the chrominance red & more compression is achieved in case of compression is done by downsampling the chrominance blue.

The algorithm as described herein works very well for coding any type of true color image. In present work, jpg format is considered. But it also works for other formats like tiff, bmp etc.

It has been extended to work on moving pictures that are beginning to play a vital role in the online distribution of film. It can be also explored to work on the Region-Of-Interest (ROI) in an image to preserve details while reducing the file size of the compressed image.

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