Adjustment of color coordinates to improve JPEG compression performance

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Abstract

JPEG is the most well-known standard for image compression and has been widely used for storing and transmitting images. JPEG has been providing quality images with reasonable compression. However, improvement is still appreciated to give better quality with less or the same bitrate. This paper proposes a new approach of color coordinate tuning (CCT) for JPEG image coding. The color coordinate rotates with a best-fit angle to maximize the variance of the Y component. The results show the effectiveness of the proposed method which outperforms the JPEG image coding standard.

Keywords: JPEG, Color Coordinate Tuning, YCbCr color coordinate, Image Coding, Matrix Rotation

1. Introduction

JPEG [1] has been the most widely used image coding standard of lossy compression for storing and transmitting photographic images. It is used for a variety of image applications requiring a compression standard, such as desktop publishing, graphic arts, color facsimile, photo videotex, newspaper wirephoto transmission, and medical imaging owing to its simple structure.

JPEG is a general purpose international standard to meet the needs of almost all continuous-tone still-image applications [2]. Although a considerable number of images distributed over the internet are compressed with JPEG [3], it still has a limitation that large volumes of data such as ITP [4], internet facsimile transmission [5],and DICOM [6] images are transmitted at a relatively lower bandwidth. Image compression presents an interesting yet challenging dilemma for the market, i.e., a tradeoff between the size of the image and image quality. When the compression ratio is increased, the quality of the image reduces, and vice versa. The challenge here, however, is to achieve the best quality with minimum size. JPEG compression ratio is typically in the range of about 10:1 to 20:1 [7].

The primary purpose of the JPEG image coding standard is to store the necessary information and to remove the redundant data from the image while compressing. This standard achieves much of its compression by exploiting the limitation of the human eye. Because the human visual system is less sensitive to the higher frequency, and by suppressing these higher frequency components, more compression is achieved.

(a) (b)

Fig. 1. General Framework of JPEG image coding standard: (a) Encoder and (b) Decoder

Many studies have focused on addressing high compression by using an appropriate color transformation, which is discussed in Section 2 briefly, such as from RGB to YCbCr. RGB color space is common and used in most computer displays along with television, cell phones, etc. which is non-linear with visual perception and device dependent. Every component of an image in RGB color space is highly correlated, therefore, they are redundant in encoding point of view. On the other hand, In YCbCr color space, Luminance or Y components are more prominent, while Chroma components have much lower entropy hence, they may be encoded more efficiently.

A general framework of JPEG is used to compress either full-color or grayscale images. In the case of color images, RGB is transformed into YCbCr color space to perform different processing on the luminance and chrominance components of the image. After color conversion, initially, DCT is applied on 8x8 blocks of the image. Afterward, quantization is performed on the DCT coefficients. A zigzag scan is carried out for each 8x8 block to exploit high-frequency components and to retain DC and low-frequency components. Then comes the lossless step where Run Length and Huffman coding are used to encode the zigzag-scanned coefficients. The image can be reconstructed through a decompression process, a reversed order of all encoding processes.The overall architecture of the coding system of JPEG is described in **Fig. 1.**

A tradeoff exists between the compression ratio and the quality of the image. The quality of the image reduces as the compression ratio is increased, and vice versa. The challenge here, however, is to achieve maximum or same compression with the best quality image.

This paper proposes a method of color coordinate tuning for the YCbCr color space. The method analyzes and finds the best-fit angle then rotates all the color components to maximize the Y component variance.

The rest of this paper is arranged as follows: Section 2 presents a brief overview about JPEG and related work. Section 3 explains our proposed CCT Algorithm. Section 4 describes the experimental setups and results. Finally, Section 5 concludes the paper and describes the future direction.

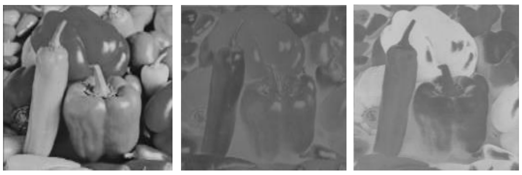
2. Related Work

Color images are commonly represented as a combination of different components, for example, red, green, and blue in the RGB color space. When the components are highly correlated, the same information is replicated during the encoding of each of the components. Hence it is suggested to convert to the image in a color space that is as decorrelated as possible. Therefore, most of the images are converted into another color space from RGB, such that YCbCr. For example, in **Fig. 2.**, all the three components of the image are more prominent regarding details of the objects in the image (edges, etc.). Compared with **Fig. 3.**, however, the Y or luminance component has most of the details about the objects in the image, while the Cb and Cr components have lower entropy or variation. Therefore, the YCbCr color space can be encoded much more efficiently by compression algorithms.

Most work has been done to improve color transform for image compression. Malvar and

(a) (b) (c) (d)

Fig. 2. RGB components : (a) Original Image (b) R-Comp (c) G-Comp and (d) B-Comp



Y-Comp Cb-Comp Cr-Comp

Fig. 3. YCbCr components

Sullivan proposed a new color model [8], called YCoCg-R, as defined below:

$$\begin{bmatrix} Y \\ Co \\ Cg \end{bmatrix} = \begin{bmatrix} 1/4 & 1/2 & 1/4 \\ -1 & 0 & -1 \\ -1/2 & 1 & -1/2 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Hyun Mun Kim *et al.* [9] have proposed a new color model, called YSbSr, which gives high decorrelation gain with small rounding and conversion error as follows:

$$\begin{bmatrix} Y \\ Sb \\ Sr \end{bmatrix} = \begin{bmatrix} 0.6460 & 0.6880 & 0.6660 \\ -1.0 & 0.2120 & 0.7880 \\ -0.3220 & 1.0 & -0.6780 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Roman Starosolski [10] proposed a simple color space transformation for lossless image compression and compared them with existing transformations.

Another color model, called CMY(K), for printing and hard copy output by Adrian Ford [11] is more dependent on the device with a type of inks and paper used, as well as a type of printing device.

Besides, Janak Porwal [12] introduced a new approach to transform a 3-dimensional RGB color space to another cGST 4-dimensional color space, and an additional dimension was introduced for the most real-life images.

However, the above-discussed methods are all about different transforms from RGB color space, while the proposed method adjusts the same YCbCr color space coordinates by rotating.

3. Proposed Method

In JPEG Standard, the first and essential step is to convert the color space of the image from RGB to YCbCr [13]. In YCbCr color space, the Y component shows the brightness, and Cb, Cr component represents the chrominance of the image. This conversion allows gains in terms of the compression by using the characteristics of the human visual system, which is more sensitive to brightness information than color information. [14].

After the conversion, the proposed CCT algorithm is applied on the image by rotating each color coordinate of YCbCr to maximize the variance of Y component.

3.1 Rotation Matrix

Let Y, Cb, and Cr component be in the x , y, and z axes, respectively, in the 3D coordinate [15], and let Y*,Cb*,Cr* are the new color coordinates obtained after rotation with an angle of φ. A 3D rotation matrix rotated around the z-axis, as shown in **Fig. 4.**, is obtained as follows:

$$\begin{bmatrix} Y^* \\ Cb^* \\ Cr^* \end{bmatrix} = \begin{bmatrix} cos\varphi & sin\varphi & 0 \\ -sin\varphi & cos\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} \quad (1)$$

Similarly, A 3D rotation matrix obtained from rotation around x-axis with an angle of rotation θ is

$$\begin{bmatrix} Y^* \\ Cb^* \\ Cr^* \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & sin\theta \\ 0 & -sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} \quad (2)$$

and rotation around y-axis having an angle of rotation $\emptyset$:

$$\begin{bmatrix} Y^* \\ Cb^* \\ Cr^* \end{bmatrix} = \begin{bmatrix} cos\emptyset & 0 & -sin\emptyset \\ 0 & 1 & 0 \\ sin\emptyset & 0 & cos\emptyset \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} \quad (3)$$

3.2 CCT Algorithm

The proposed CCT consists of the following three steps:

1. Finding variance values of each color coordinate

2. Finding the best-fit rotation angle to maximize the variance for the step 1).

3. Rotate coordinate

In the first step, the mean value for each color coordinate is calculated and subtract that average value from each sample of corresponding channel, making the median to be the center. After that, calculate the variance through the equation given as follows:

$$Y_{var} = \sum_{i=0}^{N} \frac{(Y_i - Y_{mean})^2}{N} \qquad (4)$$

Where Y_{var}, Y_i, and N are the variance, pixel value, and number of pixels respectively.

To maximize the variance in step 2), taking the partial derivative of $Y *= Ycos\varphi + Cbsin\varphi$ from 1). The best-fit angle of rotation is calculated as follows:.

$$\sum(Y^*)^2 = \sum(Ycos\varphi + Cbsin\varphi)^2$$

$$2(Ycos\varphi + Cbsin\varphi)(-Ysin\varphi + Cbcos\varphi) = 0$$

$$tan2\varphi = \frac{2YCb}{Y^2 - Cb^2}$$

$$\varphi = \frac{1}{2} atan \frac{2YCB}{Y^2 - Cb^2} \qquad (5)$$

in Step 3), rotate the color coordinates with the calculated best-fit angle in equation 5).

Similarly, Repeat the above mentioned steps to calculate the best-fit angle for other color channels.

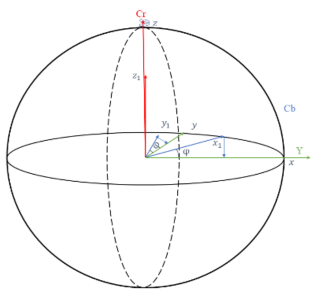


Fig. 4. Rotation about $z - axis$

4. Experiment

To show the effectiveness of the proposed method, we compared the performance with libjpeg-turbo [16], which is a reference software of the JPEG image coding standard using sample images.

4.1 Experimental Setup

After color space transformation from RGB to YCbCr, we applied the proposed CCT on the image to rotate all the color coordinates with the best-fit calculated angle to maximize the variance. **Fig. 5.** shows the sample images [17]. All sample images are compressed with different quality factors, ranging from 50 to 90.

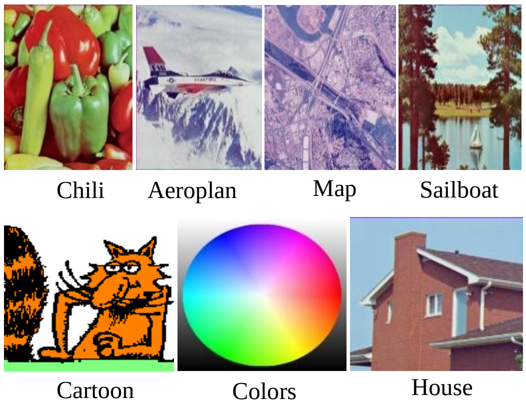


Fig. 5. Sample Images

4.2 Experimental Results

The proposed method was developed with the goal to obtain better quality of images with the same or less bitrate. **Fig. 6.** shows that the proposed method outperformed compared to libjpeg-turbo.

The quality of an image is measured in terms of PSNR against bit per pixel (BPP). Matlab application functions were used to calculate the PSNR of respective image and BPP were calculated through the formula given below:

$$\boldsymbol{BPP} = \frac{Total\ bits}{W * H}$$

Where $Total\ bits$ is the size of image (bytes)*8 and $W$and H is the width and height of the image.

5. Conclusion & Future Work

This paper investigates the behavior of color space which shows significant influences with quality having the same or less bitrate. The proposed CCT method shows that all the color coordinates with a best-fit angle rotated to maximize the variance of Y component provides an improvement of the PSNR performance.

In future we will use this on specific blocks adaptively. The specific block is to be found by using artificial intelligence techniques.

Acknowledgements

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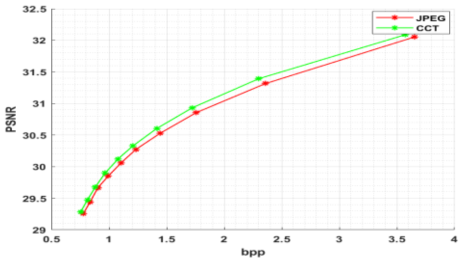
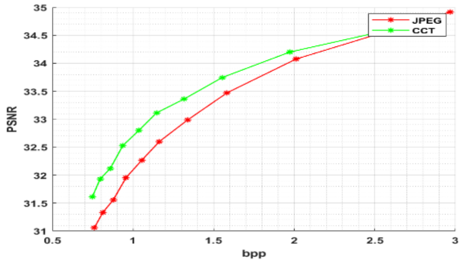
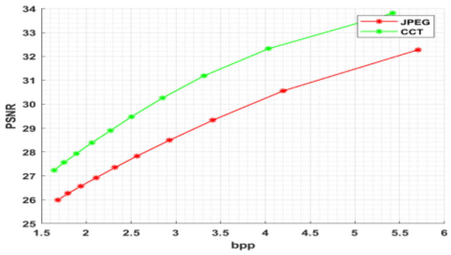


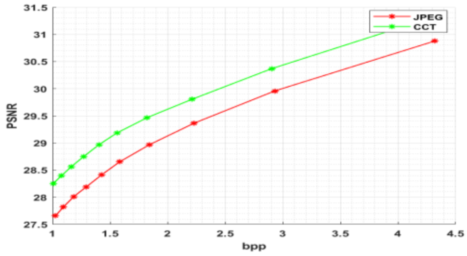
Chili



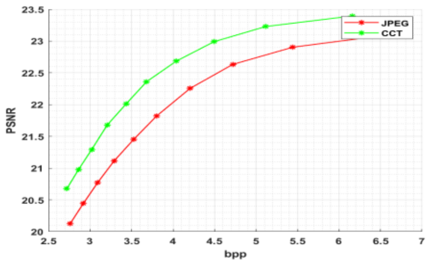
Aeroplan



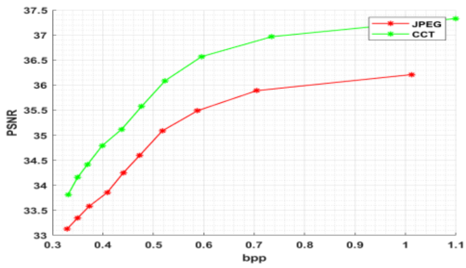
Map



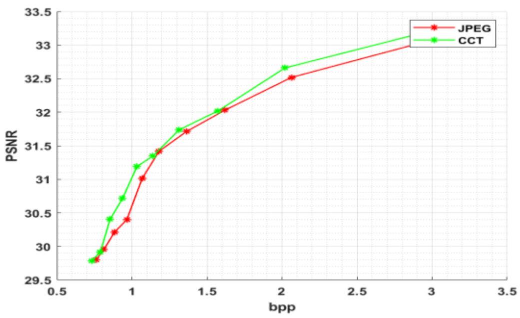
Sailboat



Cartoon



Colors



House

Fig. 6. Results