

# Enhancement of Color Contrast Using Modified DCT Coefficients in High Chroma Images

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## Abstract:

In this paper, we propose a post-processing technique developed for the improvement of color contrast in DCT-coded color images. The high frequency components caused by complex object parts are examined on DCT tables, and the correlations between luminance coefficient and Chrominance one in DCT domain are analyzed. By considering the information of relation, we modify  $C_b$ ,  $C_r$  coefficients using weighted luminance DCT coefficients. Simulation results show that the method enhances color contrast in high color saturated region, and improves the visual quality.

## Key words:

DCT, decimation, quantization, color contrast.

## 1. Introduction

Most of the international standards for image and video compression, such as JPEG [1], H.261 [2], H.263 [3], and MPEG recommend [4][5] are based on a lossy discrete cosine transform (DCT). Many kinds of artifacts in compression images have been presented, and especially at very low bit rates, these exhibit highly noticeable degradations. In these, blocking effect, mosquito noise, and bleeding effect are the most well-known ones, and several processing methods for improvement have been proposed [6]-[8].

Nevertheless, another type of artifacts has been rarely considered in color image processing. This is the reduction of color contrast by a narrower color bandwidth when compared with that of luminance. This distortion appears as a smoothing phenomenon of the color in area of high saturated chrominance. It results from lower sampling frequency and sparser quantization of the higher order AC coefficients for color elements [7][8]. The phenomenon of color smoothing is well shown in upper body in Fig. 1(b).

In this paper, we proposed a modification method of chrominance DCT coefficients to enhance the color contrast in high chroma images. First, the correlation among DCT coefficients in luminance and chrominance blocks was analyzed, and then we compensated the higher order AC coefficients of chrominance block using weighted luminance coefficients based on former correlation in DCT domain. It could be found in reconstructed image that

the proposed post-processing method improves the subjective quality of high colored image.

## 2. Analysis of color distortion in DCT

Color images are generally represented by three color components. Even though the choice of the color space used in JPEG is not specialized, the color images are generally converted from the RGB color space to the  $YCbCr$  one before being encoded, where  $Y$  is the luminance part and  $C_b$  and  $C_r$  are the chrominance part of image. The compression algorithm is applied independently to each of the three components in the same way. However, since the human visual system is less sensitive to colored details, the chrominance parts are subsampled by a factor of two in the horizontal dimension in the 4:2:2 format or by a factor of two in both the horizontal and vertical dimensions in the 4:2:0 format [9], and coarse quantization of color elements could be usually used through quantization tables shown in Table 1. The factors in tables are applied in order to strengthen compression.

The high-frequency DCT coefficients tend to be removed because of the coarse quantization in higher frequencies during encoding, and in relatively lower frequency, color components are more corrupted. Fig. 1 shows color smoothing in high colored region of the reconstructed image, and the distortion of color elements on player's body is visible.

16 11 10 16 24 40 51 61	17 18 24 47 99 99 99 99
12 12 14 19 26 58 60 55	18 21 26 66 99 99 99 99
14 13 16 24 40 57 69 56	24 26 56 99 99 99 99 99
14 17 22 29 51 87 80 62	47 66 99 99 99 99 99 99
18 22 37 56 68 109 103 77	99 99 99 99 99 99 99 99
24 35 55 64 81 104 113 92	99 99 99 99 99 99 99 99
49 64 78 87 103 121 120 101	99 99 99 99 99 99 99 99
72 92 95 98 112 100 103 99	99 99 99 99 99 99 99 99

(a)

(b)

Table 1. Quantization arrays: (a)  $Y$  component, (b)  $C_b$  and  $C_r$  components.

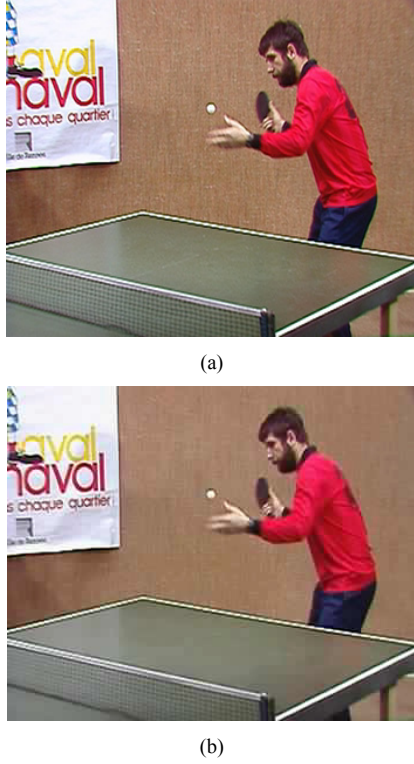


Fig. 1. Effect of chrominance process on color smoothing: (a) original, (b) DCT-coded version.

This existing phenomenon can be illustrated from an analysis of correlation in DCT coefficients through JPEG en-decoding. Fig. 2 shows differences in the activity distribution of DCT blocks before and after processing in table-tennis image. The activity of blocks in DCT field is defined by Eq. 1.

$$\text{Activity of block} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \text{DCT block}[i][j] - \text{DC element} \quad (1)$$

where  $N$  is the block size. (e.g.,  $N = 8$ ),  $\text{DCT block}[i][j]$  is the coefficient value correspond to  $i$ 'th of  $x$ -axis and  $j$ 'th of  $y$ -axis, and  $\text{DC element}$  of block is the first element in block,  $\text{DCT block}[0][0]$ .

Fig. 2(a) shows the activity distribution of input coefficients in  $Y$ ,  $Cb$ , and  $Cr$  blocks before divided by quantization factors. Due to subsampling for color elements, chrominance activities are relatively low when compared with luminance ones. Also these show that chrominance activity of DCT block increases in proportion to luminance activity of the same block. Fig. 2(b) shows the activity distribution of reconstructed coefficients through DCT process. In case of  $Y$  blocks, the decrement of block activity for whole blocks is between 200 and 250 for each, but in chrominance blocks, about 58% for  $Cb$ , and 47% for  $Cr$  are respectively lost in frequency information.

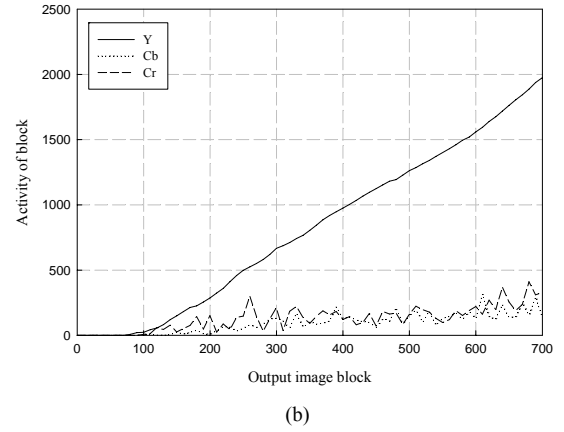
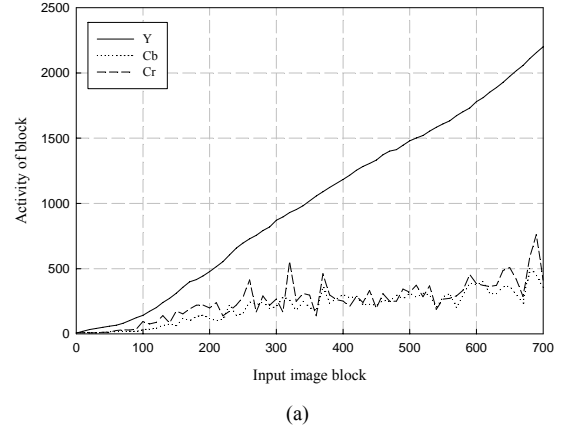


Fig. 2. Comparison of activity distribution in DCT blocks: (a) Before quantization, (b) After de-quantization.

The total distortion of chrominance is related to both decimation and quantization processes [8]. The resulting coefficients of DCT are divided by quantization factors, and then quantized. After inverse quantization, the original data of the DCT coefficients are reduced, and distortions appear in the reconstructed signal. As shown in Fig. 2.  $Y$  signals are well transported relatively. Based on these results, we develop a technique for compensating color elements in DCT in following section in order to increase the visual quality of reconstructed digital color images.

### 3. Proposed modification method in DCT table

We consider the case of chrominance signals that have been 4:2:0 down-sampled by a factor of two, in both horizontal and vertical directions, because this video format is the most employed in digital video compression algorithms (in MPEG-1, 2 or H.263). In the case of 4:2:0 chrominance signals, a macro block

contains four blocks of  $Y$ , one of  $Cb$  and one of  $Cr$ , respectively.

### 3.1 Detection of chrominance block subject to color smoothing

In previous section, the reason causing reduction of color resolution has been analyzed, and we have seen the correlation between luminance activity and chrominance one in the same block. For natural images, strong chrominance contrast is accompanied by strong luminance contrast [10], also this means that there is strong relationship among  $Y$ ,  $Cb$ , and  $Cr$  coefficients.

The flow diagram of our postprocessor is shown in Fig. 3. The proposed method can be divided into two main steps: the first one is for detecting the blocks subject to the color smoothing seen well subjectively. These selected blocks are then processed in the second part of algorithm in order to enhance color contrast.

As a first step, object region containing strong luminance edges is detected through the luminance activity calculated by Eq. (1), and next we compute the chrominance activity of each block and the colorfulness of object blocks. In order to select more visually perceptible region, the colorfulness is used as Eq. (2). Because significant chrominance edges usually corresponds to regions of higher detail in the luminance component,  $Cb$  and  $Cr$  blocks having relatively less activity in object blocks are chosen to compensate effectively chrominance elements. The threshold  $T_Y$ ,  $T_C$ , and  $T_{Cf}$  for detecting object and compensation region could be obtained experimentally.

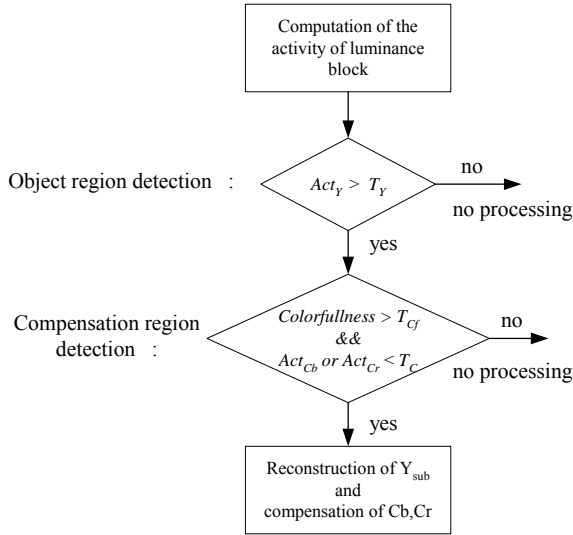


Fig. 3. Flowchart of the proposed post-processor.

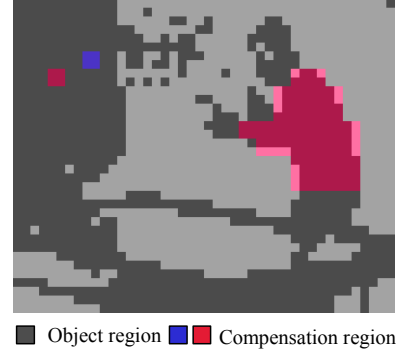


Fig. 4. Result of detection for object and compensation region in the table-tennis image. (the thresholds  $T_Y = 100$ ,  $T_C = 350$ , and  $T_{Cf} = 200$ )

Object and compensation regions marked for table-tennis image are shown in Fig. 4.  $Cb$  and  $Cr$  DCT coefficients in the region holding two regions in common will be compensated. Activity thresholds are obtained appropriately based on the activity of test image.

$$Colorfulness = |Cb[0][0]| + |Cr[0][0]| \quad (2)$$

where  $Cb[0][0]$  is DC element of  $Cb$  block, and  $Cr[0][0]$  is DC element of  $Cr$  block.

### 3.2 Enhancement of color contrast in detection region

Fig. 5 illustrates the processing of compensation for  $Cb$  and  $Cr$  block coded by DCT. First, the  $16 \times 16$  macro block, made from four adjacent blocks of  $8 \times 8$  pixels, in the selected compensation region is decoded. After inverse DCT, these are subsampled to  $8 \times 8$  block, and reconstructed to  $8 \times 8$  luminance sub-DCT block ( $Y_{sub}$ ).

Luminance components correspond to the same spatial region of chrominance ones are obtained through this process. Second, weighted factor meaning main activity ratio between luminance elements and chrominance ones is calculated. As described in the previous section, there is

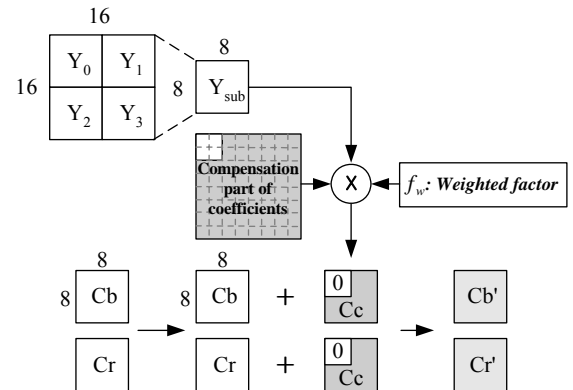


Fig. 5. Illustration of compensation processor for  $Cb$ ,  $Cr$  blocks.

a huge difference that chrominance blocks have in activity when compared with luminance ones after DCT process. The coefficient elements of luminance applied to chrominance block have to be arbitrated to meet the balance of activity between luminance and chrominance, therefore first harmonics coefficients of one and two dimensions are used to obtain the ratio as Eq. (3).

The conditional equations of compensation for each  $Cb$  and  $Cr$  blocks are presented in Eq. (4) and (5), and components vanished in the process of quantization are reconstructed but except nonzero ones.

$$f_w(B) = \frac{\sum_{i=1}^2 \sum_{j=1}^2 B[i][j]}{\sum_{i=1}^2 \sum_{j=1}^2 Y[i][j]} \quad (3)$$

$$\begin{aligned} & \text{if } (i > 1 \text{ or } j > 1) \text{ and } (Cb[i][j] == 0) \\ & \quad Cb'[i][j] = f_w(Cb) \times Y[i][j] \\ & \text{else} \\ & \quad Cb'[i][j] = Cb[i][j] \end{aligned} \quad (4)$$

$$\begin{aligned} & \text{if } (i > 1 \text{ or } j > 1) \text{ and } (Cr[i][j] == 0) \\ & \quad Cr'[i][j] = f_w(Cr) \times Y[i][j] \\ & \text{else} \\ & \quad Cr'[i][j] = Cr[i][j] \end{aligned} \quad (5)$$

where  $f_w(B)$  is a weighted factor for block  $B$  ( $B$  is  $Cb$  or  $Cr$ ),  $Y$  is a block for luminance, and  $Cb'$ ,  $Cr'$  are final blocks compensated.

#### 4. Experimental results

Computer simulations were carried out on some color images, in order to demonstrate the effectiveness of the proposed post-processing algorithm. The performance was mainly evaluated by visual judgment, because there was no effective measurement available. The peak signal-to-noise ratio (PSNR) was used for objective evaluation, but it is not well correlated with the properties of human color vision, and in this case, PSNR computed on the whole image does not reflect the localized improvement of our processing algorithm. The improvement in PSNR for  $Cb$ ,  $Cr$  each was so feeble, and actually it could not over 0.1 dB. Fig. 6(b) and Fig. 6(d) show the result of applying color contrast enhancement to the color image. It is very noticeable that color contrast has been improved in high chroma region. This is obviously true in the player's body and the flower's stamen, where the shape of color shadow is restored.

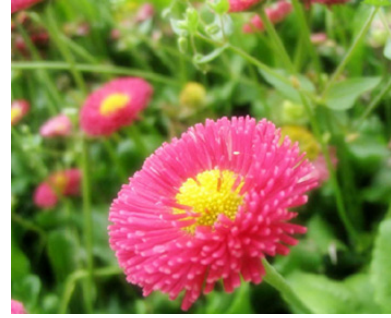
As already mentioned, this result is to be considered visually reasonable, and it's the aim of the processing technique to reduce the visual impact of the color distortion.



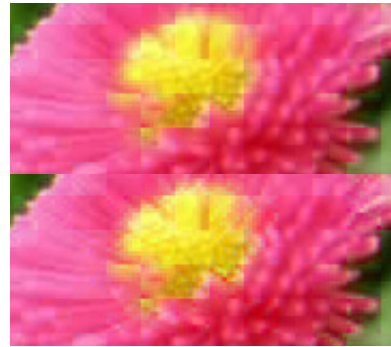
(a)



(b)



(c)



(d)

Fig. 6. Comparison of performance between conventional and proposed method: (a) test image conventionally coded, (b) test image coded by the proposed method, (c) original test image, (d) Enlarged portion of coded (c) image before and after application of the proposed method (upper part is old, and lower part is new).

## 5. Conclusions

In this paper, we proposed a post-processing method to enhance the visual color contrast only using DCT coefficients in digital color images or video sequences. After decimation and quantization, most of the chrominance coefficients are disappeared, and color resolution become reduced in view of infallible experimental results. In order to enhance color contrast in color images, we have to compensate for the corrupted chrominance data. The activities of luminance and chrominance in same block are proportioned with each other, and it is expected that chrominance blocks belongs to luminance area having high activity are relatively more distorted.

The proposed algorithm consists of two steps. First, visually corrupted color region is selected from object blocks, and then we compensated the higher order AC coefficients of chrominance block using weighted luminance coefficients based on correlation in DCT coefficients. It could be integrated in a more general digital video processing system, including the reduction of other kinds of artifacts and contributes to the improvement of the visual quality of color images.

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