ENHANCEMENT OF COLOR IMAGES BASED ON HISTOGRAM EQUALIZATION WITH VARIABLE ENHANCEMENT DEGREE

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Abstract—*The YC_bC_r. color space is suitable for image compression and adopted for JPEG and MPEG. The YC_bC_r color space is related with the HSI (hue, saturation, intensity) color space. The HSI color space is an ideal tool for developing image processing. In this paper, we propose a color image enhancement method, which is combined the intensity enhancement and the saturation enhancement, in the YC_bC_r color space. Even if the width and shape of (C_b,C_r) space is changed depending on the value of Y component, the proposed method is free from gamut problem. Furthermore, in the proposed method, the saturation enhancement degree can be altered to suit users' own preference.*

1. INTRODUCTION

Image enhancement is required mostly for better visualization or rendering image to aid our visual perception. Nowadays there is a rapid increase in the application of color video media. This has resulted in a growing interest in color image enhancement techniques. This paper specifically addresses the enhancement of digital video images.

Hue, saturation and intensity are the attributes of color [1]. Hue is that attribute of a color, which decides what kind of color it is. If hue is changed then the color gets changed, thereby distorting the image. Thus, hue preservation is an essential requirement for color image enhancement.

Several different techniques for color contrast enhancement based on 3-D histogram modification. A 3-D histogram specification algorithm in RGB cube with the output histogram being uniform is proposed by Trahanias *et al*. [2]. Mlsna *et al*. [3] proposed a multivariate enhancement technique "histogram explosion", where the equalization is performed on a histogram. This principle is later extended to CIE LUV space [4]. These techniques are effect for expansion of the histogram. However, these techniques cannot preserve the hue of color images.

Taguchi *et al*. have proposed a color image enhancement method in the YC_bC_r color space [5]. It is worth deriving the processing method for the YC_bC_r color space, since this color space is adopted for JPEG and MPEG. Furthermore, intensity, saturation and hue can be defined in YC_bC_r color space. Thus, the hue preservation enhancement method can be realized.

In [5], first, the intensity histogram equalization in consideration of the shape of color space was proposed. Next, the saturation histogram equalization was developed. Two definition of the saturation histogram are shown. Finally, the intensity histogram equalization and the saturation histogram equalization are combined. The proposed method is free from the gamut problem and can preserve the hue information. However, this method cannot change the enhancement degree. The enhancement degree is too high for some images. It is pity that some images are degraded by this method.

In order to overcome the defect of [5], this paper presents the saturation enhancement method with variable enhancement degree. The variable enhancement degree is realized by assuming the range of equalization to be changeable. The enhancement degree can be altered to suit users' own performance. The proposed method ensures the improvement of the image quality. The variable enhancement method is also combined with the intensity histogram equalization in consideration of the shape of color space.

Furthermore, the other two saturation enhancement methods with variable enhancement degree are proposed. One method is used γ -correction in saturation enhancement. The other method is that the saturation value is multiplied by α . These two methods are compared with the proposed histogram equalization method.

2. COLOR SPACE

In JPEG and MPEG encoder, color space is transformed from RGB to YC_bC_r. On the other hand, in the decoder, inverse transformation is done. "Recommendation ITU-R BT.601" [6] defines these transformations as follows:

[RGB to YC_bC_r]

$$\begin{aligned} Y &= 0.257R + 0.504G + 0.098B + 16 \\ C_b &= -0.148R - 0.291G + 0.439B + 128 \\ C_r &= 0.439R - 0.368G - 0.071B + 128 \end{aligned} \quad (1)$$

[YC_bC_r to RGB]

$$\begin{aligned} R &= 1.164(Y-16) + 1.596(C_r - 128) \\ G &= 1.164(Y-16) - 0.391(C_b - 128) - 0.813(C_r - 128) \\ B &= 1.164(Y-16) + 2.018(C_b - 128) \end{aligned} \quad (2)$$

The variance range of each component of RGB space is 0-255 (i.e., 8bits). Thus, the variance range of Y, C_b and C_r are 16-235, 16-240 and 16-240, respectively. The origin of the (C_b, C_r) plane is shifted to (128,128).

Transformation from one space to another and processing in these spaces usually generate gamut problem. We would like to show the gamut condition for YC_bC_r color space. The conditions of C_b and C_r are the function of Y as follows.

$$139.669 - 0.729Y \le C_r \le 299.444 - 0.729Y \quad (3)$$

$$-2.079C_r + (2.97Y - 305.657) \le C_b \le -2.079C_r + (2.97Y + 346.517) \quad (4)$$

$$137.229 - 0.577Y \le C_b \le 263.592 - 0.577Y \quad (5)$$

These conditions are illustrated in Fig.1. Figure 1 shows that the shape and area of the gamut region for (C_bC_r) plane is changed to a large extend according to the value Y.

3. EHNCEMENT OF COLOR IMAGES BASED ON HISTOGRAM EQUALIZATION

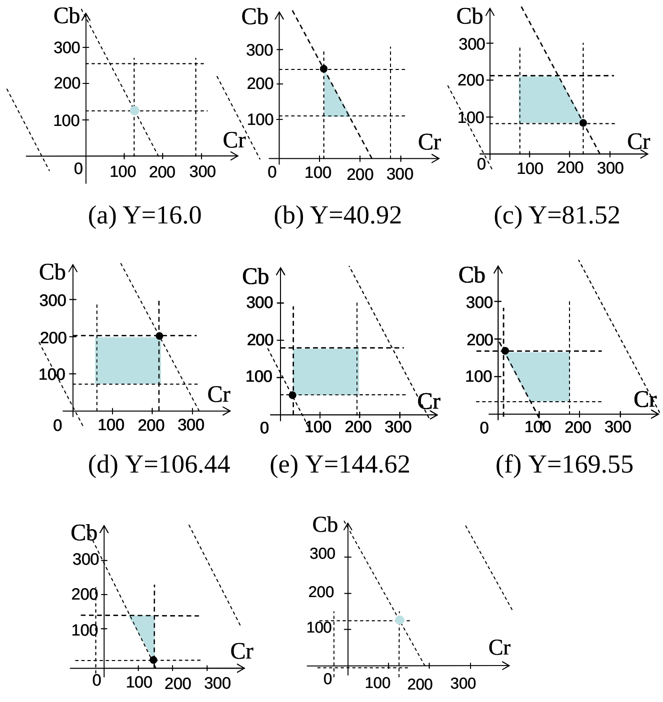
3.1 Intensity Histogram Equalization [5]

In the YC_bC_r color space, the shape and area of the gamut region for (C_bC_r) plane is changed depend on the value Y, thus, the signal distribution is concentrated the low and high value of Y, if we apply the normal histogram equalization method [1] to the intensity histogram. The aria of (C_bC_r) plane of each value Y, is shown as Fig.2. In order to extend the signal distribution the whole of YC_bC_r color space, it is necessary to translate the intensity histogram shown as Fig.2, which is called the intensity histogram equalization for the YC_bC_r color space.

The intensity histogram equalization method for the YC_bC_r color space realizes that any histogram of Y component is transform to the histogram, which is shown in Fig.2. The procedure of this transformation method is explained in Ref.[1].

3.2 Saturation Histogram [5]

In order to show the saturation histogram equalization, it is necessary to define a saturation histogram. Saturation is the length from the origin (i.e., C_b=C_r=128) on the (C_b, C_r) plane. From Fig.1, the range of saturation is depended on the value of Y and the hue. It is difficult to define the saturation histogram for color images in this situation.



(a) Y=16.0 (b) Y=40.92 (c) Y=81.52

(d) Y=106.44 (e) Y=144.62 (f) Y=169.55

(g) Y=210.15 (h) Y=235.0

Fig.1 Gamut region for (C_bC_r) plane

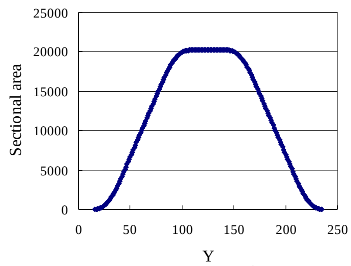


Fig.2 Gamut aria for each Y

We normalize the distance from the origin to the boundary of the gamut region of the (C_b, C_r) plane for all hue. Thus, YC_bC_r color space is translated to the cylindrical color space shown as Fig.3. In this cylindrical color space, the length from the origin to the any boundary points of the gamut region is unit length. In this color space, the (C_b, C_r) plane is a circle. The saturation histogram for each intensity value is can be derived by counting the number of signals, which are existed on equal distance area from the center point of the (C_b, C_r) plane. Those histograms are added and one histogram is obtained for one image.

3.3 Saturation Histogram equalization with variable enhancement degree

The range of the saturation histogram is from 0 to 1. In [5], histogram equalization is applied to the all range of saturation histogram, which was called "Equalization I". In this case, the saturation histogram equalization does not show the good results from a subjective evaluation viewpoint for certain kinds of image, since the shape of the distribution of original images is quite different from that of the enhanced images. Thus, there is a need to develop the enhancement method with variable enhancement degree.

In this paper we present the saturation histogram equalization with variable enhancement degree. The saturation histogram is made by the above-mentioned method. The equalized range for the saturation histogram is assumed to be changeable. That is, the saturation histogram is equalized from 0 to S. In the case of S=1, the proposed method is equivalent to the "Equalization I" in [4].

We combine the intensity histogram equalization and the saturation histogram equalization same as [4]. The intensity histogram equalization is applied first, is better.

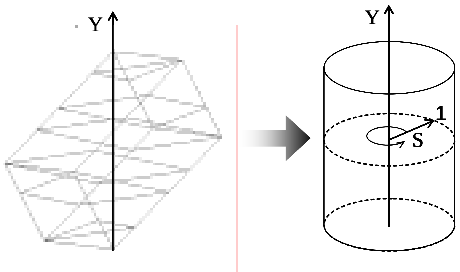


Fig.3 Transformation of the color space

4. SUBJECTIVE EVALUATION

We evaluate the proposed method through the comparison of the other methods. We prepare 4 methods as follows.

Method (A):
The simple intensity histogram equalization

Method (B):
The intensity histogram equalization mentioned in **3.1**

Method (C):
Method (B) + Equalization I [5]

Method (D)
Method (B) + Proposed method (i.e., **3.3**)

Four color images shown in Fig.4 are used for the evaluation. These four images (balloon, couple, girl, airplane) are unclear and we can evaluate the effectiveness of the enhancement method by using these images.

The number of the observers is 10 young men. Observer grades the enhanced images on a scale of one to five (5: excellent, 4: good, 3: fair 2: poor, 1:bad).

Table 1 shows the results of the subject evaluation. From this Table, the proposed method (i.e., Method (D)) shows the best results. We also show the average value S of ten observers in Table 1. The suitable value S of each image is different. It is not necessary for "airplane" to emphasis the contrast, since the suitable value S shows small value. Thus, the result of Method (C) for "airplane" is bud. The proposed method with variable enhances degree shows good result regardless of the kinds of images.

Next we show the enhancement results by applying the Methods (A)-(D) on "couple" in Fig.5. From Fig.5(c), saturation histogram equalization degrades the quality of the image since it leads to very large saturation values that are not present in the natural scenes. That is, the enhancement degree is too high for this image. On the other hand, the proposed method (S=0.6) the excellent result is obtained as Fig.5(d). We can understand that the proposed method (i.e., Method (D)) also shows the best result from Fig.5.

(a) balloon

(b) couple

(c) girl

(d) airplane

Fig.4 Test images

5. THE OTHER TWO SATURATION ENHANCEMENT METHODS

The other two saturation enhancement methods with variable enhancement degree are introduced. These two methods use saturation of the cylindrical color space shown in Fig.3. We explain two methods as follows:

Method (1)

The saturation value is multiplied by α . In order to emphasize the saturation, α should be set as larger than 1.

Method (2)

γ-correction [1] is applied to the saturation value. In order to emphasize the saturation, γ should be set as smaller than 1.

We also combine the intensity histogram equalization and the above two methods. The enhancement results are shown in Fig.6. We choose α and γ according to the subjective evaluation.

The above two methods also show the excellent result. However the vividness is less than Method (D). The histogram equalization method is effective for enhancement.

Table 1 Evaluation of the enhancement results

	Original	(A)	(B)	(C)	(D)
balloon	2.7	1.1	1.9	2.5	4.4(0.69)
couple	1.3	1.9	2.9	2.7	4.3(0.57)
girl	1.6	1.5	2.9	2.7	4.5(0.52)
airplane	3.2	1.6	3.1	2.4	3.2(0.28)

Method (D) ( ) : Average value of S

6. CONCLUSION

In this paper, we have proposed the color image enhancement method with variable enhancement degree in the YC_bC_r color space without gamut problem. We combined the proposed histogram equalization method with the intensity histogram equalization method for the YC_bC_r color space. The effectiveness of the combination method is shown through the subjective evaluation and the visual evaluation of the enhanced image.

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(a) Method (A) (b) Method (B)

(c) Method (C) (d) Method (D)

Fig.5 Enhanced images (1)

(a) Method (1) (α =1.7) + Method(B) (b) Method (2)(γ=0.55) +Method(B)

Fig.6 Enhanced images (2)