

Color Image Enhancement by Histogram Equalization in Heterogeneous Color Space

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Abstract

This paper presents a luminosity conserving and contrast enhancing histogram equalization method for color images. The histogram equalization is one of the ordinary methods employed for enhancing contrast in TV and images for consumer electronics where unwanted subjective deterioration are frequently occur. Although there have been many solutions to overcome the drawback of histogram equalization, however the method is for RGB color space, which is not well suited for different color spaces. To do this, we use fuzzy set to improve histogram equalization. All RGB images are firstly transformed into different color spaces, and particular channels are applied histogram equalization process. From our 20 test LC images show that HSV color space yields the favorable results in MSE by giving the luminosity conserving ability.

Keywords: *color image enhancement, histogram equalization, color space.*

1. Introduction

The image enhancement to meet human visual perception is an important issue in general image processing, coding, machine vision. Nowadays, image enhancement is also widely adopted for medical image processing, texture synthesis, and speech recognition [1]. The main purpose of image enhancement is to enhance the edge contrast of image/video. Therefore, the tool of image enhancement process works by distinguishing edge borders in the image so as one can distinguish background from a subject.

Histogram equalization uses stochastic probability distribution of each channel level of color images [2]. Therefore histogram equalization has been one of the well used approaches for improving the image contrast or conserves the luminosity of image. Normally it has two stages: smooth stage and stretch stage. After both processes, the contrast is expected to be improved. There have been various methods to try to model and reproduce the human visual perception mechanism [3-5]. Most of them focus gray-level image enhancement. They are found well fit for enhancement and thresholding of gray-level images, however as we approach more color images these methods are not well suited in color spaces.

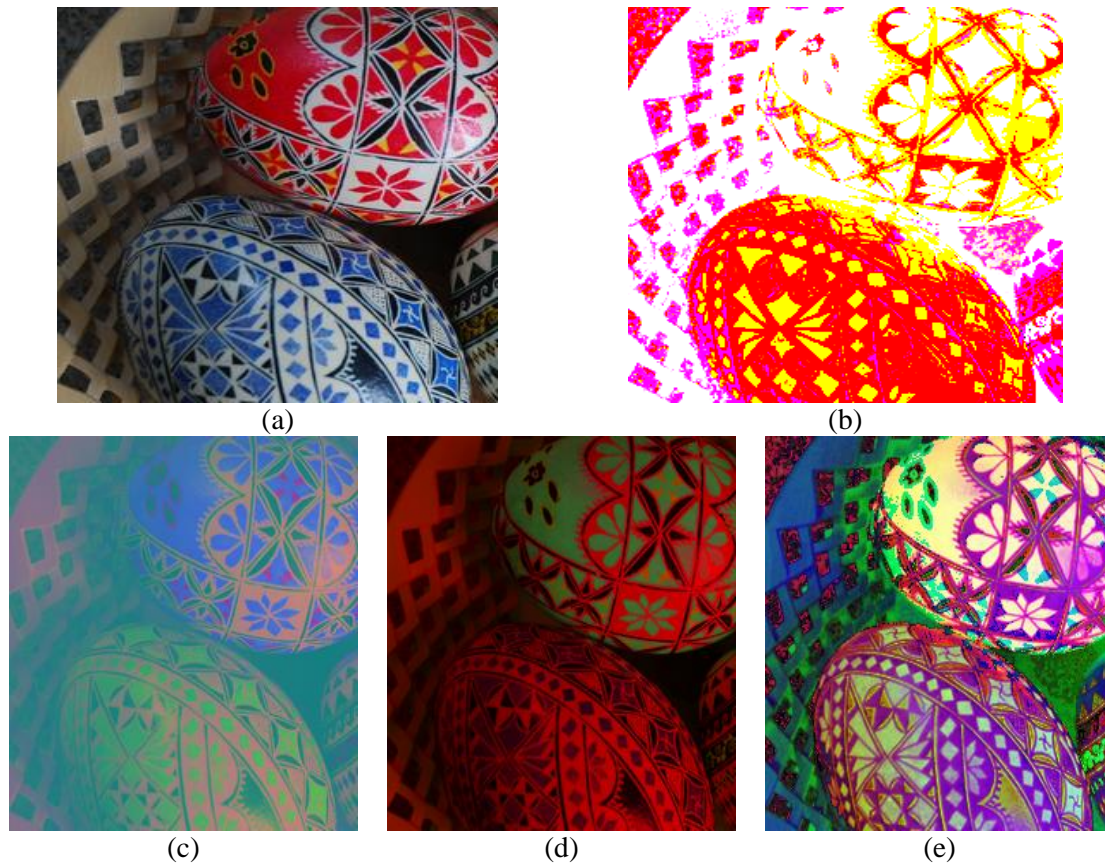
One of the most popular methods for contrast enhancement is histogram equalization. The histogram equalization is widely used because of its simplicity. There are many modifications of this approach [6-14], and the summary of those approaches can be found [8].

In this paper, we propose luminosity conserving and contrast enhancing histogram equalization method for images in different color channels. The original RGB color image is transformed into four color spaces, LAB, YIQ, YCbCr, and HSV, then the luminance channels are applied histogram equalization process. The rest of the paper is arranged as follows. Section 2 yields brief introduction of color spaces and the proposed color image

enhancement methods. Section 3 presents some simulation results of applying the proposed method into four color spaces, and then the paper concludes in section 4.

2. Proposed Method

The RGB color space is an additive color model where R (red), G (green), and B (blue) light are supplemented together in individual ways to restore a wide array of possible colors. The opposite model is CMYK (cyan, magenta, yellow, and key) color space which is a subtractive color model for color printing. The principal goal of the usage of RGB color space is to display images in electronic systems. However, sometimes it is better to use other color spaces (LAB, YCbCr, YIQ, and HSV). One reason we can consider is that sometimes non-RGB color space is advantageous due to its detail nature.



**Figure 1. (a) Display of LC #127 Image in Different Color Spaces
(a) RGB Color Space, (b) LAB Color Space, (c) YCbCr Color Space, (d) YIQ
Color Space, and (e) HSV Color Space**

The purpose of LAB (CIELAB) color space is to represent a color space which is more perceptually linear than the other color spaces [15]. The YIQ color space and YCbCr color space have been used in NTSC or PAL TV systems. The Y channel stands for luminance value while the other two channels represent chrominance components. The YIQ color space is rotated 0.1833π concerning the YCbCr color space. The HSV color space has three components, hue, saturation, and value (or brightness). HSV is well used by color scientist because HSV color space is more natural to deal with. Moreover, RGB is used for

implementation details concerning the way RGB displays color, while HSV shows the actual color components. Therefore the way of RGB representation is for computer, while the way of HSV representation is for human visual perception system. In other words, RGB image exists as 24 bits per pixel color coding, thus RGB color space does not have inherent relation to the natural color properties or human perception. Thus any inter-channel arithmetical operation is not applicable in RGB space. On the other hand, other color spaces such as LAB, YCbCr, YIQ, and HSV are applicable. Therefore, converting the color space from RGB to other color spaces is useful because one can perform the color interpolation or possible image processing process. After the process, one can re-convert the operated values back to RGB color space. Figure 1 shows an LC #127 image with different color spaces, i.e. RGB, LAB, YCbCr, YIQ, and HSV.

To convert RGB color space image to LAB color space image, we need to obtain XYZ color space image first [15]. Equation (1) shows the transformation matrix:

$$\begin{bmatrix} \mathbf{X} \\ \mathbf{Y} \\ \mathbf{Z} \end{bmatrix} = \begin{bmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{bmatrix} \begin{bmatrix} \mathbf{R} \\ \mathbf{G} \\ \mathbf{B} \end{bmatrix} \quad (1)$$

Now, one can obtain LAB color space. L^* is obtained as Eq. (2).

$$\begin{aligned} L^* &= 116 \times \left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} - 16, & \text{for } \frac{Y}{Y_n} > 0.008856, \\ L^* &= 903.3 \times \frac{Y}{Y_n}, & \text{for } \frac{Y}{Y_n} \leq 0.008856. \end{aligned} \quad (2)$$

where X_n , Y_n , and Z_n are the tristimulus values of the reference white. a^* and b^* are obtained as

$$a^* = 500 \times \left\{ f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right) \right\}, \quad (3)$$

$$b^* = 200 \times \left\{ f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right) \right\}, \quad (4)$$

where $f(t)=t^{1/3}$ (for $t>0.008856$) or $f(t)=7.787 \times t + 16/116$. Therefore X, Y, Z components are obtained,

$$\begin{aligned} X &= X_n \times \left(P + \frac{a^*}{500} \right)^3, \\ Y &= Y_n \times P^3, \\ Z &= Z_n \times \left(P - \frac{b^*}{200} \right)^3, \end{aligned} \quad (5)$$

where $P=(L^*+16)/116$.

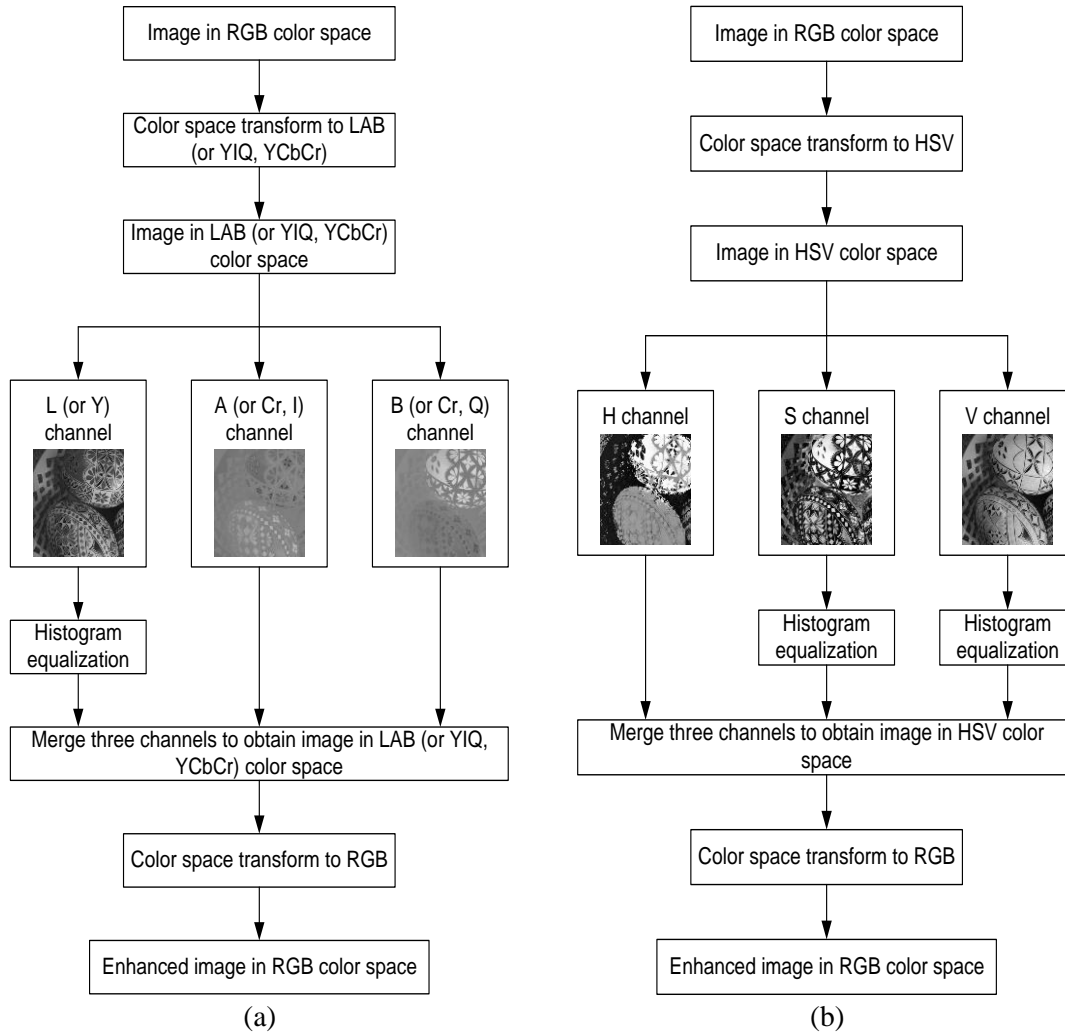


Figure 2. Flowchart of the Luminosity Conserving Image Enhancement process: (a) Case of LAB, YCbCr, and YIQ Color Spaces, (b) Case of HSV Color Space

We adopted conventional histogram equalization method introduced in [4-14]. The used approach is composed of five stages: smooth the histogram with Gaussian filter, fuzzy histogram computation, partitioning of the histogram, equalize each partition independently, and normalization of the image brightness. The flowchart of luminosity conserving image enhancement process is introduced in Figure 2. The process includes color space transform and inverse transform processes. The histogram equalization process is applied pre-determined channels such as L of LAB color space, Y or YIQ and YCbCr color spaces, and S and V of HSV color space. Note that the other color channels are unchanged and merged with the processed luminance color components.

3. Simulation Results

In this section, we provide some simulation results of our proposed approach on different color spaces, LAB, YCbCr, YIQ, and HSV. The test images were obtained from LC dataset

[16], particularly we obtained 20 images (#111 to #130). These test images are shown in Figure 3.



Figure 3. Twenty Test Images: LC #111 to #130

Table 1. Average MSE and PSNR Performance for 20 Test Images

Color space	MSE				PSNR (dB)			
	R	G	B	RGB	R	G	B	RGB
LAB	182.3560	195.7824	199.1165	192.4183	27.6335	27.4327	27.5186	27.4819
YCbCr	182.2176	195.8653	194.5135	190.8655	27.5799	27.3649	27.4359	27.4524
YIQ	164.2432	167.2463	168.9725	166.8207	27.7935	27.7501	27.7130	27.7505
HSV	56.1992	64.9873	91.4610	70.8825	31.7629	32.0058	30.2991	31.0177

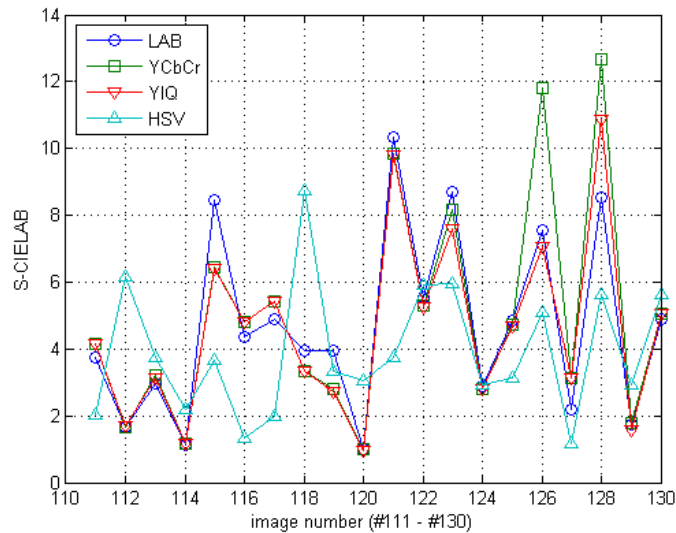


Figure 4. S-CIELAB Performance Comparison on Four Color Spaces: LAB, YCbCr, YIQ, and HSV

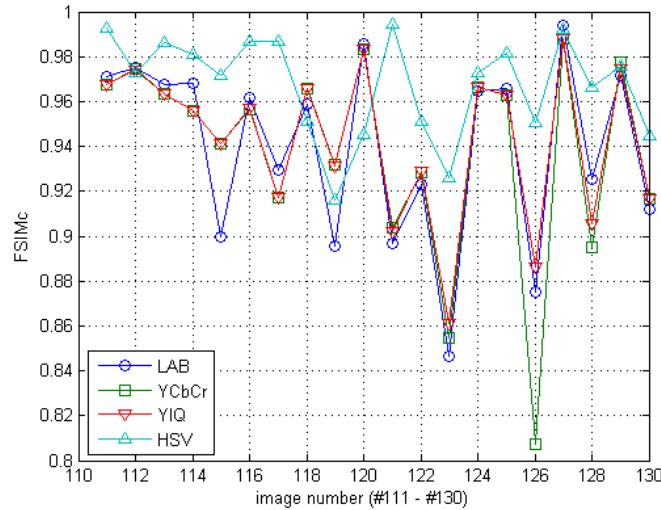


Figure 5. FSIMc Performance Comparison on Four Color Spaces: LAB, YCbCr, YIQ, and HSV

Table 1 shows the average MSE and PSNR performance for 20 test images. From Table 1, we can see that HSV color space gives the lowest MSE in red, green, blue, and total color channels of reconstructed image. The YIQ, YCbCr are the second and the third best color spaces, and the LAB color space was the worst. This results is identical in PSNR (dB) case. The HSV color space gives the best average PSNR results (31.0177 dB), which is 3.5358 dB, 3.5653 dB, and 3.2672 dB better performance than LAB, YCbCr, and YIQ, respectively. Note that LAB color space gives better performance than YCbCr in PSNR result by 0.0295 dB margin, while YCbCr is better than LAB in MSE (-4.603).

Figure 4 shows the S-CIELAB performance comparison on four color spaces. The average S-CIELAB performance are 4.6657 (LAB), 4.9653 (YCbCr), 4.5826 (YIQ), and 3.9160 (HSV). Note that S-CIELAB value close to 0 implies better performance. From this result, we see HSV is the best color space for our proposed method. Although YCbCr is the worst color space in average results, however YCbCr is not the worst except for #126 and #128. This implies that the best color space is dependent on the image characteristics. Figure 5 shows the FSIMc performance comparison on different color spaces. The average FSIMc performance are 0.9394 (LAB), 0.9379 (YCbCr), 0.9425 (YIQ), and 0.9673 (HSV). Note that higher FSIMc (close to 1) implies better performance. As we can see, HSV found to be the best color space for our proposed method, followed by YIQ, LAB, and YCbCr color spaces.

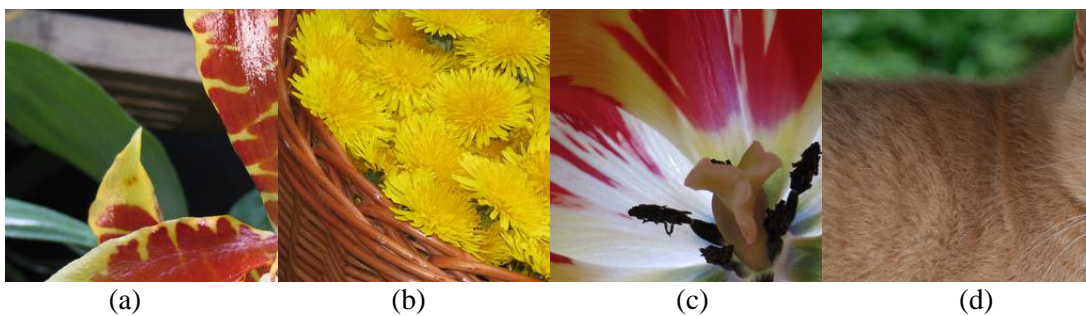


Figure 6. Original test images for visual comparison: (a) #124, (b) #128, (c) #129, and (d) #130

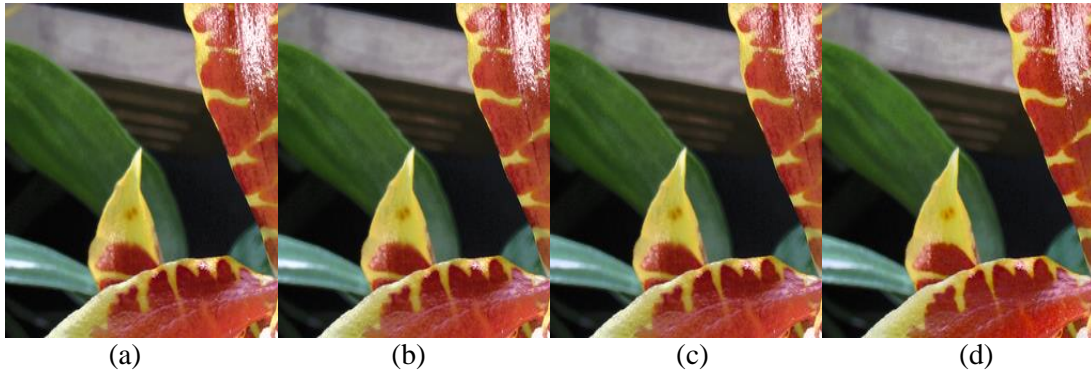


Figure 7. Subjective performance comparison in heterogeneous color space using LC #124 image: (a) LAB color space, (b) YCbCr color space, (c) YIQ color space, and (d) HSV color space



Figure 8. Subjective performance comparison in heterogeneous color space using LC #128 image: (a) LAB color space, (b) YCbCr color space, (c) YIQ color space, and (d) HSV color space

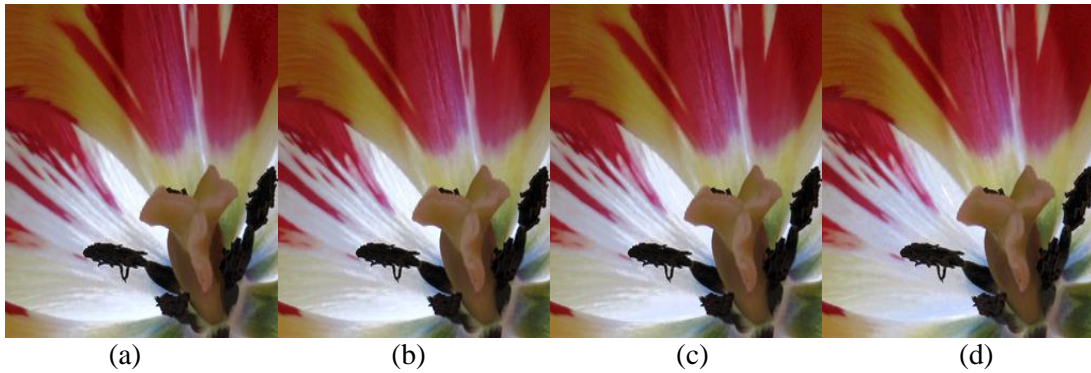


Figure 9. Subjective performance comparison in heterogeneous color space using LC #129 image: (a) LAB color space, (b) YCbCr color space, (c) YIQ color space, and (d) HSV color space

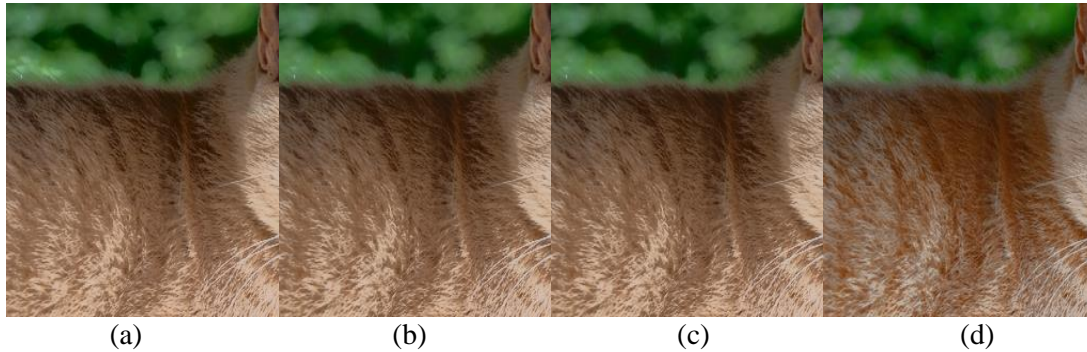


Figure 10. Subjective performance comparison in heterogeneous color space using LC #130 image: (a) LAB color space, (b) YCbCr color space, (c) YIQ color space, and (d) HSV color space

Figure 6 shows four test images #124, #128, #129, and #130. The improved images on each color spaces are shown in Figs. 7-10. Figures 7-10 show all images are well improved. In particular, images improved in HSV color space gives the best visual images while reserving the mean brightness.

4. Conclusions

A luminosity conserving and contrast enhancing histogram equalization method for color images was presented. In literature, various histogram equalization methods for gray-level images have been proposed. However, they are not well-suited in color space. In this paper, original image is transformed in other color spaces, and histogram equalization process is applied in particular channels. Simulation results show that the HSV color space gives the best performance.

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