A Novel Color Image Processing Scheme in HSI Color Space with Negative Image Processing

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Abstract—**While emphasizing the intensity or saturation component in order to obtain high-quality color images, keeping the hue component unchanged is important; thus, perceptual color models such as HSI and HSV were used. Hue-Saturation-Intensity (HSI) is a public color model, and many color applications are commonly based on this model. However, the transformation from the HSI model to RGB model after the processing intensity and saturation in the HSI model usually generates the gamut problem, because, the HSI gamut is larger than the RGB gamut. Nevertheless, the common area of RGB gamut and HSI gamut is large to the middle value of the intensity. In this paper, we propose a new color image processing scheme in HSI color model. In the proposed scheme, the positive image processing and the negative image processing are performed in parallel. Since we can realize the negative processing system which is equivalent to the normal (i.e., positive) processing system, the proposed scheme is same degree-of-freedom of the normal processing scheme. In the negative image processing, color images are treated as CMY color space. The common area of CMY gamut and HSI gamut is large from the middle value of the intensity. Therefore, if the intensity value until middle, we choose the positive image processing result as the final result of our scheme. On the other hand, if the intensity value larger than middle value the result of negative image processing result is chosen as the final result. Due to that, we can almost avoid the gamut problem by the proposed scheme.**

Keywords- RGB color model, CMY color model, HSI color model, gamut, negative image processing

I. INTRODUCTION

Many color models have been proposed for various applications. One of well-known color models is the hue-saturation-intensity (HSI) color model [1]. The HSI color model describes a color in terms of how it is perceived by the human eye [2]. Hue is that attribute of a color which decides what kind color it is, i.e., a red or an orange. Saturation shows the vividness of color and has effect on the impression of the image. For the purpose of enhancing a color images, it is to be seen that hue value should not change for any pixel. If hue value is changed, thereby distorting the image. For general hue-preserving color image processing, the original RGB image is usually transformed to another color space such as HSI or HSV, then, the intensity/saturation components is processed, but the hue component remains unchanged.

However, transforming from one space to another and processing in these spaces usually generates gamut problem. In general, this problem is tackled either by clipping the out of boundary values to the bounds or by normalization [3]-[5]. Clipping the values to the bounds creates undesired shift of hue. In the case of the transformation from HSI color space to RGB color space, the gamut problem is also occurred. In fact, the HSI gamut quite larger than RGB gamut is cleared in [6]. The saturation component of the HSI color space is always increased with increasing intensity component. Thus, the possibility of occurring the gamut problem increases if the processed intensity value is large. However, the common area of the gamut of RGB and HSI color models is large to the middle value of intensity component.

In this paper, we propose the new color image processing scheme in order to avoid the gamut problem. In the proposed processing scheme, the positive (i.e., normal) image processing and the negative image processing are performed in parallel. We can realize the negative image processing system which is equivalent to the normal image processing system. Therefore, the proposed processing scheme is same degree-of-freedom of the normal processing scheme.

If the normal (i.e., positive) image processing performed in RGB color space, the negative image processing is considered as performed in CMY color space. The negative intensity is defined in CMY color space. The normal intensity range which is larger than middle value corresponds to the negative intensity range which is until middle value. Therefore, the common area of the gamut of CMY and HSI color spaces is large from the middle value of normal intensity. Then, if the output intensity value until middle, we choose the positive image processing result as the final result of our processing scheme. On the other hand, if the output intensity value larger than middle, the result of negative image processing is chosen as the final result. Due to that, we can almost avoid the gamut problem by the proposed scheme.

II. THE RELATIONSHIP BETWEEN THE RGB GAMUT AND THE HSI GAMUT

A. Transformation formula

Firstly, we show the transformation formula between RGB color space and HSI color space [1].

(1) From RGB color space to HSI color space

It is assumed that the RGB values have been normalized to the range [0,1].

Intensity I is defined as

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Table 1 Conversion from HSI color space to RGB color space

H	0°-120°	120°-240°	240°-360°
	$H=H$	$H=H-120$	$H=H-240°$
C_1	B	R	G
C_2	R	G	B
C_3	G	B	R

$$I = \frac{1}{3}(R+G+B) \quad (1)$$

The range of the intensity is [0,1]. The hue component is obtained as

$$H = \begin{cases} \theta & if \quad B \le G \\ 360-\theta & if \quad B > G \end{cases} \quad (2)$$

where

$$\theta = \cos^{-1}\left[\frac{\{(R-G)+(R-B)\}/2}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right]$$

The saturation component is given by

$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)] \quad (3)$$

The range of saturation is also from 0 to 1.

(2) From HSI color space to RGB color space

C_1, C_2 and C_3 are defined as shown in Table 1, then, transformation formula from HSI color space to RGB color space is given as follows:

$$C_1 = I(1-S) \quad (4)$$

$$C_2 = I\left[1+\frac{S\cos H}{\cos(60°-H)}\right] \quad (5)$$

$$C_3 = 3I-(C_1+C_2) \quad (6)$$

B. The Relationship between RGB gamut and HSI gamut

We clear the relationship between the RGB gamut and the HSI gamut.

Two color spaces are shown in Fig.1. The diagonal which links point (1,1,1) to point (0,0,0) of RGB color space is equivalent to the intensity (I) axis of the HSI color space. Seeing from point (1,1,1) to RGB color space, RGB color space is shown as the regular hexagon such as Fig.2. The center point of the regular hexagon corresponds to the diagonal line from (1,1,1) to (0,0,0). The hue is defined as Fig.2. That is, red corresponds to 0° and green and blue correspond to 120° and 240°, respectively.

Now, we study about the volume of two color spaces. The RGB color space is the cube whose length of a side is 1. Thus, the volume of the RGB color space is 1. On the other hand, HSI color space is the triangular pyramid. The area of the bottom face is $9\sqrt{3}/2$ and the height is $\sqrt{3}$. The volume of the HSI color space is 9/2 and 4.5-times of the volume of the RGB

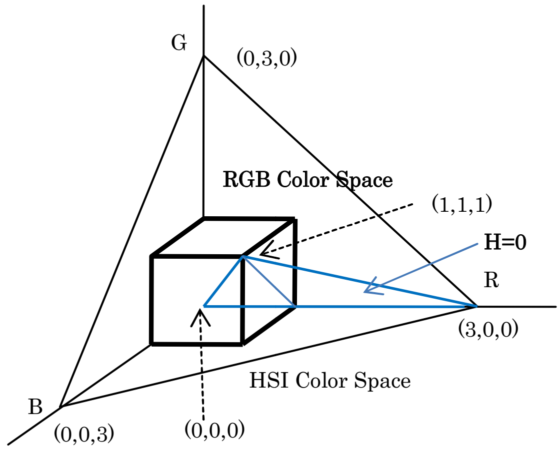


Fig.1 RGB color space and HSI color space

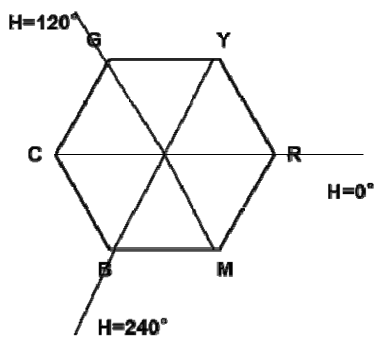


Fig.2 Seeing from point (1,1,1) to RGB color space

color space. We can understand that the HSI gamut is quite larger than the RGB gamut. However, in the condition of $I \le \frac{1}{2}$, the common gamut area of HSI and RGB color spaces is large. The volume of the HSI color space and the RGB color space are 9/16 and 1/2 respectively under the condition of $I \le \frac{1}{2}$. Thus, the volume of the HSI color space is only 1.125-times of that of the RGB color space.

III. New Color Image Processing Scheme

A. Negative image

A positive image is a normal image. A negative image is a total inversion, in which high intensity areas appears low intensity and vice versa. A negative color image is additionally color-reversed, with red areas appearing cyan, greens appearing magenta and blues appearing yellow. This means that if the normal image is defined in the RGB color space, the negative image is defined in the CMY color space.

The CMY component is defined by C=1-R, M=1-G, and Y=1-B. Furthermore, the relationship between CMY gamut and HSI gamut is can be shown by Fig.3. The common area of the gamut of CMY and HSI color models is large from the middle value of normal intensity component. We can easily understand that the gamut problem is almost avoided by the combining

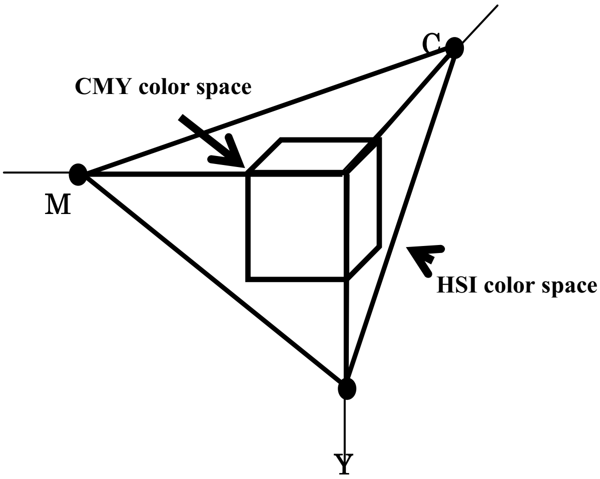


Fig.3 CMY color space and HSI color space

the positive (i.e., normal) image processing and the negative image processing.

B. New color image processing scheme

We show the new color image processing scheme. Figure 4 shows a block diagram of the proposed processing scheme. The positive image processing and the negative image processing are performed in parallel.

First we explain about the positive image processing part.

(a) Positive image processing part

Input image is converted from RGB color space into HSI color space by using Eq.(1)-(3). Intensity $I(i,j)$ and saturation $S(i,j)$ are processed by using transformation functions $f()$ and $g()$, respectively. Thus, the outputs of intensity and saturation are given by

$$I_{out}(i,j) = f\{I_{in}(i,j)\} \tag{7}$$

$$S_{out}(i,j) = g\{S_{in}(i,j)\} \tag{8}$$

Where $I_{in}(i,j)$ and $I_{out}(i,j)$ are input and output of intensity, respectively. In like manner, $S_{in}(i,j)$ and $S_{out}(i,j)$ are input and output of saturation, respectively. Hue component of input image is unchanged (i.e., $H_{out}(i,j)=H_{in}(i,j)$).

The output image is converted from HSI color space into RGB color space by using Eq.(4)-(6).

(b) Negative image processing part

In the negative image processing part, positive/negative inversion is performed and C, M, and Y components of the input image are obtained. Then we use C, M and Y instead of R, G and B, in Eq.(1)-(3) and obtain $\overline{H}_{in}(i,j)$, $\overline{S}_{in}(i,j)$ and $\overline{I}_{in}(i,j)$.

The saturation output of negative image processing part is given as follow.

$$\overline{S}_{out}(i,j) = g\{\overline{S}_{in}(i,j)\} \tag{9}$$

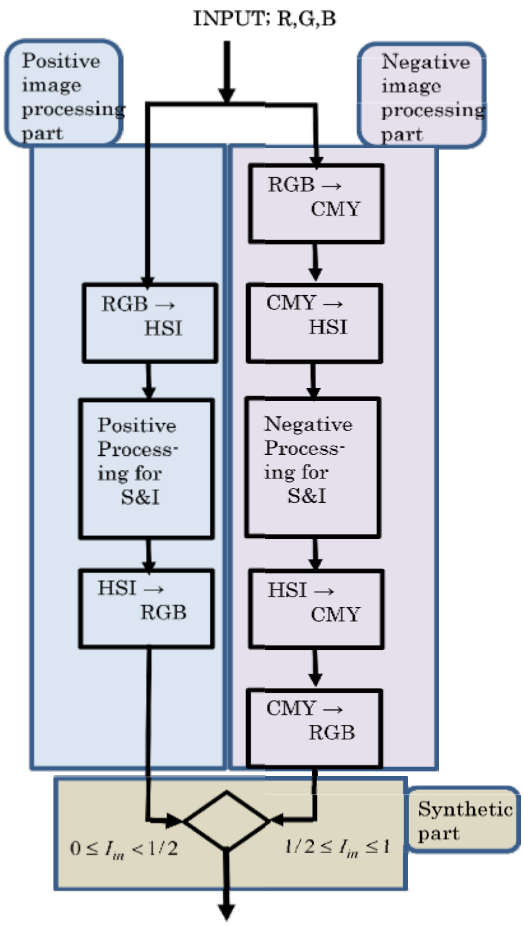


Fig 4 The block diagram of the proposed processing scheme

The transformation function of saturation of the negative image processing part is same as that of the positive image processing part.

The intensity output of negative image processing is given by

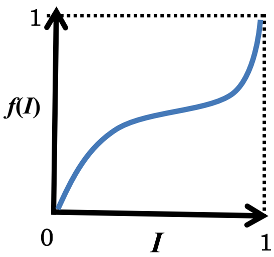
$$\overline{I}_{out}(i,j) = 1 - f\{\overline{I}_{in}(i,j)\} \tag{10}$$

It is necessary to modify the transformation function of intensity for the negative image processing part in order to make the output of negative image processing part is same as that of positive image processing part. We show how to derive the modified transformation function in Fig.5. Hue component of input image is unchanged same as the positive image processing part.

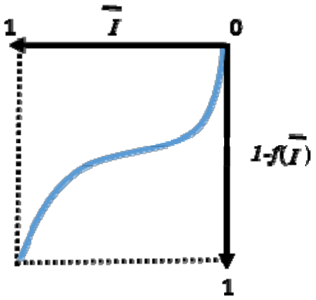
C, M and Y components of output image are derived by Eq.(4-6). C, M and Y correspond to C_1, C_2 and C_3 in Eq.(4-6) Finally, R, G, and B components of output image are given as R=1-C, G=1-M, B=1-Y.

(c) Synthetic part

We can easily synthesize two outputs. If $I_{out}(i,j)$ is smaller than 0.5, the output of positive image processing is chosen.



(a) Positive processing for intensity



(b) Negative processing for intensity

Fig.5 Negative image processing for intensity component

(a) Original image

(b) Positive processing

(c) Negative processing

(d) Proposed scheme

Fig.6 The proposed processsing scheme

Otherwise the output of negative image processing is chosen.

IV. Experimental Results

In this chapter, we apply the histogram equalization to intensity component and saturation component independently for enhancement color image.

First, we compare the outputs of positive image processing, negative image processing and proposed processing scheme by using Lena which is 8-bit for each component.

Figure 6(b) shows the output of positive image processing. We can see hue shifting at the background part. On the other hand, from Fig.6(c) the output of negative image processing is insufficient the degree of enhancement. The synthetic result of the positive image processing and the negative image processing shows the good enhancement result without hue shifting from Fig.6(d).

Next, two images (i.e., “flower” and “house”) are also prepared for enhancement (see Fig.7). These images are 8-bit for each component too.

Figure 8 shows the results of “flower”. In the output of the positive (normal) image processing (i.e., Fig.8(a)), we can easily recognize the hue shifting at the red flower part and the green grass part. Figure 8(b) shows the output of proposed scheme result. The good enhancement result is obtained by the proposed processing scheme included red flower part and green grass part. 30.6% pixels of the normal image processing result are located outside of the RGB gamut. On the other hand, only 2.8% output pixels are located outside of the RGB gamut in the proposed scheme.

(a) flower

(b) house

Fig.7 Test images

Figues 9 shows the results of “house”. This image has the high contrast/colorfulness, thus, does not need enhancement. The hue shifting is occuerd on the blue sky part of the normal processing result (i.e., Fig.9(a)). 31.5% and 1.9% pixels are located outside of the RGB gamut in the normal processing result and the proposed processing result, respectively. The proposed image processing scheme can almost avoid the gamut problem. Fouthermore, good results are obatined even if we apply our scheme to unnecessary images for enhancemet.

V. Conclusion

HSI is a perceptual color model; many applications on color image enhancement, segmentation and recognition have been developed based on this model. The transformation from HSI model to RGB model after processing intensity and saturation in the HSI model, usually generates the gamut problem because