RYB Color Compositing

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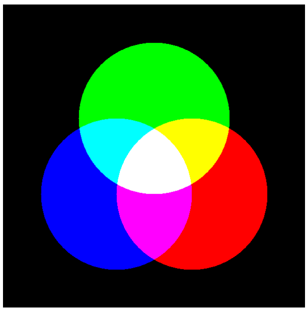
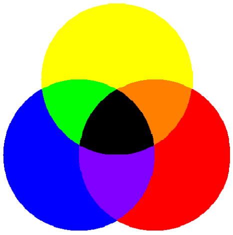


(a) RGB color compositing



(b) RYB color compositing

(c) Itten's RYB color wheel

(d) Stroke compositing in RYB color space

Fig. 1. Intuitive color compositing

***Abstract*—This paper introduce an equation to convert from RGB to RYB and the inverse conversion equation as a model of RYB color space. Proposal RYB color model allows paint like compositing easily without complex configuration of parameters such as Kubelka-Munk model.**

***Keywords*— RYB; Color; Compositing; Mixing**

I. Introduction

Color compositing is a commonly used operation in computer graphics. There are two general approach: either compositing in RGB color space, or physical model using Kubelka-Munk (KM) theory [1]. However, the former fails to reproduce paint like appearances, while the latter is difficult to use.

Most computer graphics applications make use of the RGB color space which is defined by the three chromaticities of the red, green, and blue primaries. The RGB color model is an additive color model (See Fig. 1. (a)). Simple alpha blending in RGB color space maps onto the traditional color compositing pipeline. However, RGB color compositing fails to reproduce paint like appearance such as "*yellow and blue makes green*".

CMYK is well known color model for subtractive color compositing used in printing. Similar to RGB, CMYK also fails to reproduce paint like appearance.

Many people have been used subtractive color model based on pigment color compositing since early childhood. RYB color model by Johannes Itten is widely used in art education [2]. Fig. 1. (c) shows Itten's RYB color wheel. In the RYB color model, red, yellow and blue are defined as primary colors. Red and yellow makes orange, yellow and blue makes green, and red and blue makes purple. Composited three colors get close to black (See Fig. 1. (b)).

Meanwhile, there is a physical model for compositing pigments such as that of KM model [3], [4], [5]. The KM model is able to analytically calculate reflectance and transparency of scattering materials such as paint pigment. However, it is difficult to use because the KM model requires many parameters. In addition, KM model has the limitation of usable colors due to a requirement of predefined pigment library.

For compositing colors that more closely resemble the expectations of those not trained in the RGB color space, the RYB color space is thought of as intuitive approach. For this reason, modelization of the RYB color space on computer is useful and several application can be expected.

This paper introduce an equation to convert from RGB to RYB and the inverse conversion equation. By converting RYB color space with the conversion equation, we regain normal use of simple color compositing method in RYB color space, for example alpha-blending, without complex configuration of parameters such as KM model. Experimental results verify the effectiveness of proposal RYB color model.

II. Related Work

There are a number of extensive studies on physical pigment model to calculate the compositing color for realistic natural digital media painting system. However, there is few study on converting color space from RGB to RYB.

Several digital media painting system have used KM model for producing composited colors [3], [4], [5]. Baxter et al. [6] proposed a strokes paint system using KM model with a numerical approximation of the same pigments. Curtis et al. [6] used reduced KM model for rendering watercolor. Wang and Wang [7] proposed further approximation which uses a single coefficient variant of KM model. The wax crayon simulation of Rudolf et al. [8] uses simple approximation of KM model.

However, KM model is difficult to use because this model requires many parameters. Moreover, usable colors is limited to the number of predefined pigment library.

In order to improve the problem, Lu et al. [10] proposed a data-driven model for compositing colors. Although this model not requires complex configuration of parameters but requires predefined colors as an input.

Gossett and Chen [11] proposed paint inspired RYB color model. As far as we examined, this is the only research to convert from RGB to RYB. Gossett and Chen defined three paint pigment primaries and tri-linearly interpolated among them. However, this model is irreversible conversion, because interpolated color is depend on defined pigment primary colors. And this paper do not provided clear mechanism for converting RYB to RGB.

These and other studies provided useful information. However, the conversion equation from RGB to RYB has not been generally provided in the literature.

III. RYB COLOR MODEL

In this chapter, we describe the method of interconversion between RGB and RYB color space. Ideal correspondence values between RGB to RYB show Table 1. The number of each RGB or RYB channel ranges from 0 to 1. We propose the conversion equation in agreement with the values of Table 1.

TABLE 1. CORRESPONDING VALUES BETWEEN RGB AND RYB

Color	RGB	RYB
	(0, 0, 0)	(1, 1, 1)
	(1, 0, 0)	(1, 0, 0)
	(0, 1, 0)	(0, 1, 1)
	(0, 0, 1)	(0, 0, 1)
	(1, 1, 0)	(0, 1, 0)
	(1, 0, 1)	(1, 0, 0.5)
	(0, 1, 1)	(0, 0.5, 1)
	(1, 1, 1)	(0, 0, 0)

A. RGB to RYB Conversion

We introduce how to make the conversion from the RGB to RYB color space. R_{rgb}, G_{rgb}, B_{rgb} are given RGB values as an input. Whiteness component is removed from R_{rgb}, G_{rgb}, B_{rgb} by the following equation.

$$\begin{aligned} r_{rgb} &= R_{rgb} - I_w \\ g_{rgb} &= G_{rgb} - I_w \\ b_{rgb} &= B_{rgb} - I_w \end{aligned} \tag{1}$$

Here, I_w can be calculated as follows:

$$I_w = \min(R_{rgb}, G_{rgb}, B_{rgb}) \tag{2}$$

Here, min() is a function for calculating min value from input arguments. RYB values, r_{ryb}, y_{ryb}, b_{ryb}, are obtained from r_{rgb}, g_{rgb}, b_{rgb} by the following equation.

$$\begin{aligned} r_{ryb} &= r_{rgb} - \min(r_{rgb}, g_{rgb}) \\ y_{ryb} &= \frac{g_{rgb} + \min(r_{rgb}, g_{rgb})}{2} \\ b_{ryb} &= \frac{b_{rgb} + g_{rgb} - \min(r_{rgb}, g_{rgb})}{2} \end{aligned} \tag{3}$$

We normalize the equation (3) as:

$$\left.\begin{aligned} r_{ryb}' &= \frac{r_{ryb}}{n} \\ y_{ryb}' &= \frac{y_{ryb}}{n} \\ b_{ryb}' &= \frac{b_{ryb}}{n} \end{aligned}\right\} \quad (n > 0) \tag{4}$$

Here, n is calculated as follows:

$$n = \frac{\max(r_{ryb}, y_{ryb}, b_{ryb})}{\max(r_{rgb}, g_{rgb}, b_{rgb})} \tag{5}$$

Here, max() is a function for calculating max value from input arguments.

Finally, black component are added for subtractive color mixing, and RYB values, R_{ryb}, Y_{ryb}, B_{ryb}, are obtained as follows:

$$\begin{aligned} R_{ryb} &= r_{ryb}' + I_b \\ Y_{ryb} &= y_{ryb}' + I_b \\ B_{ryb} &= b_{ryb}' + I_b \end{aligned} \tag{6}$$

Here, I_b can be calculated as follows:

$$I_b = \min(1 - R_{rgb}, 1 - G_{rgb}, 1 - B_{rgb}) \tag{7}$$

B. RYB to RGB Conversion

In this section, we describe the conversion from RGB to RYB. R_{ryb}, Y_{ryb}, B_{ryb} are given RYB values as an input. Whiteness component is removed from R_{ryb}, Y_{ryb}, B_{ryb} by the following equation.

$$\begin{aligned} r_{ryb} &= R_{ryb} - I_w \\ y_{ryb} &= Y_{ryb} - I_w \\ b_{ryb} &= B_{rgb} - I_w \end{aligned} \tag{8}$$

Here, I_w is calculated as follows:

$$I_w = \min(R_{ryb}, Y_{ryb}, B_{ryb}) \tag{9}$$

RGB values, r_{rgb}, g_{rgb}, b_{rgb}, are obtained from r_{ryb}, y_{ryb}, b_{ryb} by the following equation.

$$\begin{aligned} r_{rgb} &= r_{ryb} + y_{ryb} - \min(y_{ryb}, b_{ryb}) \\ g_{ryb} &= y_{ryb} + 2\min(y_{ryb}, b_{ryb}) \\ b_{rgb} &= 2\left(b_{ryb} - \min(y_{ryb}, b_{ryb})\right) \end{aligned} \tag{10}$$

We normalize the equation (10) as:

$$\left.\begin{aligned} r_{rgb}' &= \frac{r_{rgb}}{n} \\ g_{rgb}' &= \frac{g_{rgb}}{n} \\ b_{rgb}' &= \frac{b_{rgb}}{n} \end{aligned}\right\} \quad (n > 0) \tag{11}$$

Here, n is calculated as follows:

$$n = \frac{\max(r_{ryb}, g_{ryb}, b_{ryb})}{\max(r_{rgb}, y_{rgb}, b_{rgb})} \tag{12}$$

Finally, black component are added, and RGB values, R_{rgb}, G_{rgb}, B_{rgb}, are obtained as follows:

$$\begin{aligned} R_{rgb} &= r_{rgb}' + I_b \\ G_{rgb} &= g_{rgb}' + I_b \\ B_{rgb} &= b_{rgb}' + I_b \end{aligned} \tag{13}$$

Here, I_b can be calculated as follows:

$$I_b = \min(1 - R_{ryb}, 1 - Y_{ryb}, 1 - B_{ryb}) \tag{14}$$

IV. Experimental Results

To verify effectiveness of proposed RYB model, the authors performed several experiments.

A. Results of Color Compositing

Fig. 1. (b) shows the result using proposed RYB color model. Composited color C_{comp} is calculated from two colors, C_1, C_2, by following equation.

$$C_{comp} = C_1 + C_2 \tag{15}$$

As shown in Fig. 1. (b), we could observe the paint like compositing such as "*yellow and blue make green*".

Fig. 1. (d) shows result of stroke compositing in the proposed RYB color space. This results used alpha blending method which is defined by following equation.

$$C_{blend} = \alpha C_1 + (1 - \alpha) C_2 \tag{16}$$

C_{blend} is composited color from C_1 and C_2. α is 0.5 in Fig. 1. (d). As shown in Fig. 1. (d), we could observe the paint like appearance. By using the proposed RYB color space, we regain normal use of simple alpha blending method for compositing colors. The proposed RYB color model allows paint like compositing easily without complex configuration of parameters such as Kubelka-Munk model.

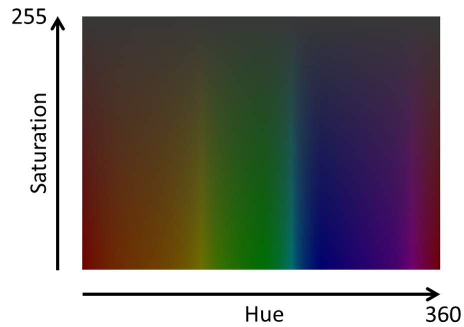
B. Whole context of proposed RYB Color Model

To understand the whole context of the proposed RYB color model, we converted from RYB to HSL color space. For comparison, we also converted from RGB to HSL color space. Fig. 2. shows relationship between hue and saturation in HSL color space. The vertical axis is luminance, the horizontal axis is hue. The number of hue ranges from 0 to 360, saturation and luminance ranges from 0 to 255. Fig. 2. (a) and (b) show results for the case of luminance = 100. As shown in Fig. 2. (b), we can observe alignment sequence of colors that same as RYB color wheel (Fig. 1. (c)): that is to say the order of colors are red, orange, yellow, green, blue, purple. Fig.2. (c) and (d) show results as luminance = 200. Fig. 2. (c) is brighter than Fig. 2. (a) because RGB is additive color model. On the other hand, Fig. 2. (d) is darker than Fig. 2. (b). It means that the proposed RYB color model realized subtractive color model.

(a) RGB (Luminance = 100)

(b) RYB (Luminance = 100)

(c) RGB (Luminance = 200)



(d) RYB (Luminance = 200)

Fig. 2. Comparison of hue between RGB and RYB

C. *Conversion Error*

We calculated the conversion error between RGB and RYB. The input RGB values used is Table 1. Conversion error was not observed in the values. It would appear that proposed equations are invertible conversion.

D. *RYB Color Compositing Chart*

Color chart is often used in order to observe how different pigments appear when layered. In this section, we compare a visual appearance between physical chart and composited chart by proposed model. Fig. 3. (a), (c), (e) show physical chart in different media which are gouache (Fig. 3. (a)), thin acrylic (Fig. 3. (c)), watercolor (Fig. 3. (e)) respectively. These charts derived from the paper of Lu et al. [10]. In addition to the Lu's chart, we also used a chart for serving as an example of guide available online (Fig. 3. (g)). Color mixing guide chart is intended for understand in how to mix the colors we see based on actual tube color combinations.

The results of generated chart by the proposed RYB color model show Fig. 3. (b), (d), (f), (h). These are results generated by using alpha blending method in proposed RYB color space. The alphas α are 0.8, 0.85, 0.6 and 0.5 respectively. There are difference of brightness but it seems that hue is assigned to almost same category. With the use of RYB color space, paint like appearance can be realized by simple alpha blending method.

V. Conclusions

We proposed an interconversion equation between RGB and RYB color space. Several experiments verified that the whole context of proposed RYB color model were characterized and precision of interconversion between RGB and RYB were exhibited. From results of stroke and color chart compositing, it was also noted that paint like compositing are realized with the use of RYB color space. Future work will focus on quantitative evaluation of proposed model and comparison to other compositing technique.

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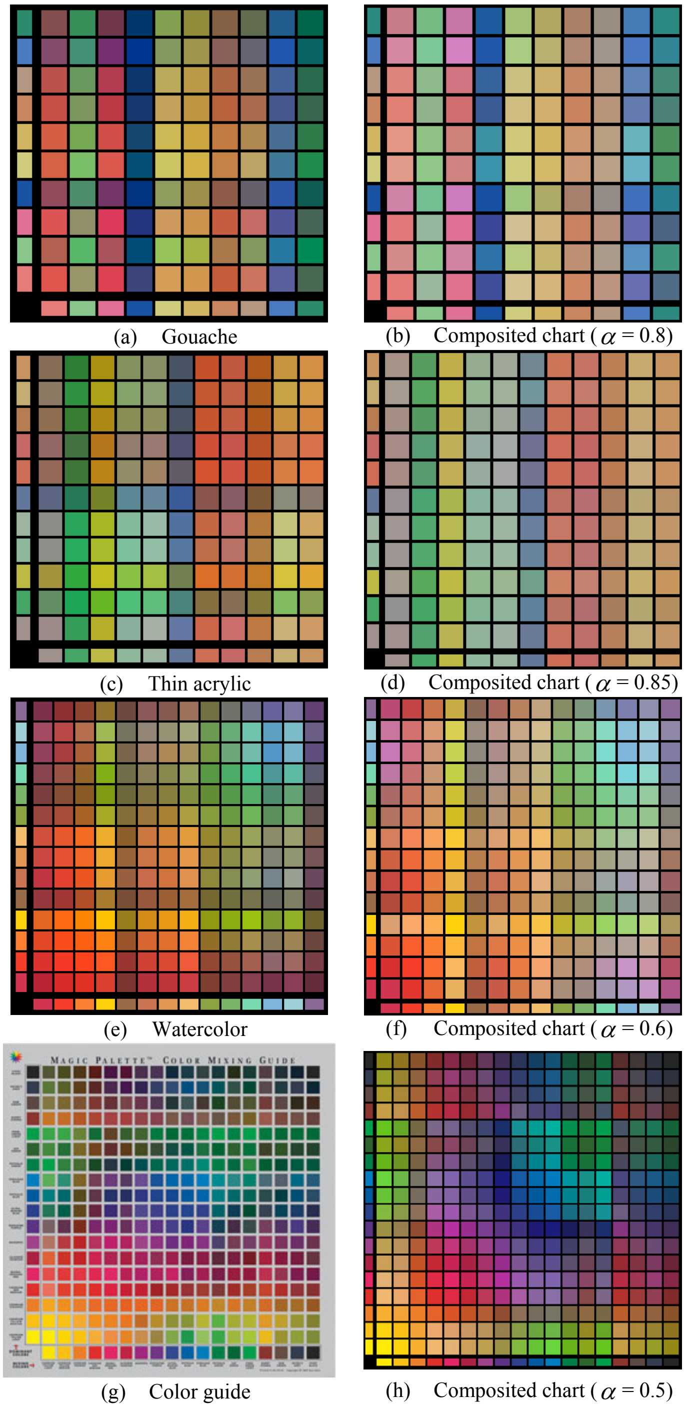

(a) Gouache
(b) Composited chart ($\alpha = 0.8$)
(c) Thin acrylic
(d) Composited chart ($\alpha = 0.85$)
(e) Watercolor
(f) Composited chart ($\alpha = 0.6$)
(g) Color guide
(h) Composited chart ($\alpha = 0.5$)

Fig. 3. Comparison between physical chart in different media and synthetic color compositing chart using alpha blending in our RYB model.