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Pixel Arrangement and Mapping Algorithm for Improving Saturation and Brightness

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Abstract

With the increasing demand for display effects and resolution in the display market, the traditional RGBW permutation has defects such as reduced display saturation and poor image restoration. A new sub-pixel arrangement is designed for these defects, reducing the number of white pixels W and adding yellow pixels Y, which reduces the influence of white pixels on surrounding pixels compared to the conventional RGBW structure. According to the new arrangement method, two new mapping algorithms are designed, and the saturation concept is introduced. The yellow component and the white component are adjusted by the saturation change to effectively improve the image saturation. The simulation shows that the new mapping algorithm (1) has a higher degree of restoration on the image and increases the saturation by 10%. The new mapping algorithm (2) can improve the brightness based on maintaining the high saturation of the original image.

Keywords: pixel arrangement; RGBW; mapping algorithm; saturation; brightness.

1. Introduction

Liquid crystal display panels and organic light-emitting diodes (OLED) display panels are mostly composed of red (R), green (G) and blue (B) sub-pixels to form a light-emitting unit [1]. With the increasing demand for display effects and resolution in the market, the traditional RGB arrangement has shortcomings such as poor light transmittance, low brightness, and poor visibility under sunlight. It has been difficult to meet market demands, so researchers have developed a new RGBW arrangement form [2].

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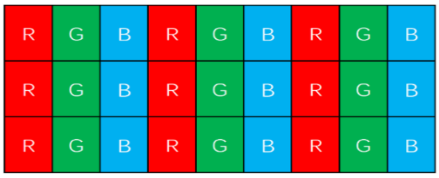
The RGBW structure was first proposed by LG Display, and its structure is to add a white W sub-pixel to the traditional RGB three-pixel. Since the white sub-pixel has low requirements on the filter structure, its light transmittance is three times that of other sub-pixels [3], which effectively increases display brightness and reduces power consumption, so that the screen has good permeability and brightness. However, after adding white sub-pixels, in the case of the same number of pixels, the white pixels have high brightness, and the brightness of the adjacent pixels is encroached, and the white component will take away the RGB component values, resulting in a decrease in peripheral pixel saturation, and the image is dim, affecting feeling of watching [4]. In addition, the RGB signal needs to be converted by the mapping algorithm to adapt to the RGBW device. However, the RGB to RGBW mapping algorithm does not have a unified conversion standard. Mobile phone panel manufacturers are now actively following RGBW to enhance the display effects of the screen in the sun. However, industries such as notebooks that do not have high brightness requirements are removing the RGBW arrangement form which is because of the drop of feeling of watching caused by white pixels. In order to solve the problems caused by white pixels, this paper proposes a new RGBWY pixel arrangement form, which adds yellow (Y) pixels to the traditional RGBW form to improve the image saturation, and designs two kinds of mapping schemes suitable for RGBWY. Balance the yellow (Y) and white (W) pixel components to improve the feeling of watching of the image.

2. Pixel arrangement form

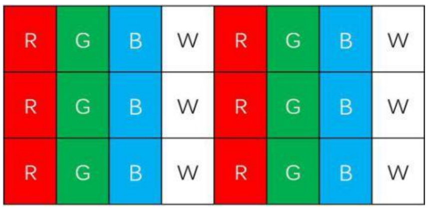
2.1. Traditional sub-pixel arrangement form

The traditionalnal RGB arrangement form is arranged in red, green, and blue pixels, as shown in Figure 1. Currently, RGBW display devices are divided into strip RGBW display form, as shown in Figure 2 [5-6]. Figure 3 shows Samsung's Pentile arrangement [7]. Due to the addition of white pixels, the number of pixels is increased by 1/3 compared to the RGB form, which proposes higher demands on the process [8]. Taking the stripe RGBW arrangement as an example, the white pixel is located between the red pixel and the blue pixel, which inevitably affects the display effect of the left and right red and blue pixels [9]. The existing solution is to reduce the blue pixel and white pixel area to achieve a pixel area shared by white and blue, which can reduce the blue laser of the screen and reduce the influence of white light on the display. However, the reduction of the area of the blue pixel still causes problems such as color cast, and the reduction of the white pixel area may result in poor screen brightness [10-11]. In order to solve this problem, Samsung proposed a Pentile arrangement, using interlaced pixel arrangement to reduce the area affected by white pixels, but sawtooth appear on the display edge, and the display brightness is significantly reduced. Sharp has proposed a four-color technology, introducing a new yellow sub-pixel, using a large number of yellow pixels to achieve a wider color gamut than R, G, B, but also brings the problem of insufficient brightness [12-13].



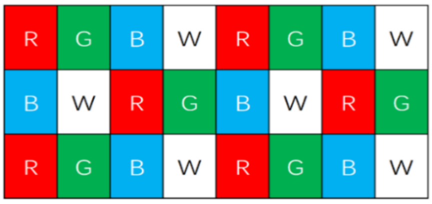
R	G	B	R	G	B	R	G	B
R	G	B	R	G	B	R	G	B
R	G	B	R	G	B	R	G	B

Figure 1: Traditional RGB arrangement



R	G	B	W	R	G	B	W
R	G	B	W	R	G	B	W
R	G	B	W	R	G	B	W

Figure 2: Strip RGBW arrangement

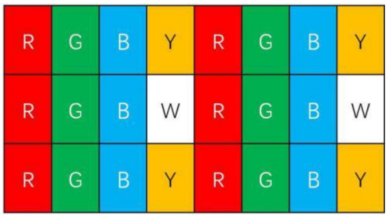


R	G	B	W	R	G	B	W
B	W	R	G	B	W	R	G
R	G	B	W	R	G	B	W

Figure 3: Pentile arrangement

2.2. New RGBWY arrangement

The new RGBWY structure proposed in this paper is shown in Figure 4. This arrangement is to compensate for the problem that the original yellow pixel is insufficient in brightness, and the arrangement is divided into odd lines and even lines. An odd row consists of a set of display units consisting of RGBY, and an even row consists of a set of display units consisting of RGBW. As shown in Figure 5, yellow = red + green, that is, yellow pixels can emit red and green components, and double color light is emitted on a single pixel, which is why yellow pixels can improve the saturation in the same pixel density. White pixels will cause color encroachment on the surrounding 8 pixels. Blue pixels and red pixels are especially serious. Yellow pixels can be used as a complement to blue and red, which not only compensates for the color encroachment of white pixels on surrounding pixels, but also enhances blue and red expressiveness. The even-line white pixels remain unchanged, arranging for RGBW, increasing the brightness of the entire screen. The problem of color encroachment of white pixels on the upper and lower yellow pixels also compensates for the color cast problem caused by yellow pixels.



R	G	B	Y	R	G	B	Y
R	G	B	W	R	G	B	W
R	G	B	Y	R	G	B	Y

Figure 4: RGBWY arrangement

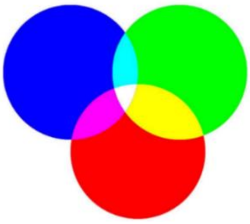


Figure 5: Three primary colors

With the help of yellow pixels, the screen does not need to increase the brightness of the backlight or the transmittance of the liquid crystal to get a better feeling of watching. In the case of not changing the total number of pixels on the screen and supplying power, a brighter white is obtained, and as a result, the RGBWY arrangement is finer and brighter in the same environment.

3. RGBWY signal mapping algorithm

3.1. Traditional signal mapping algorithm

The traditional mapping algorithm calculates R, G, and B proportionally, and the output is the same as the input R, G, and B ratios [14]. The advantage of this scheme is that it does not theoretically change the image saturation during the calculation phase [15-17]. The algorithm is calculated as follows:

$$R_0 = \frac{R_i \times \left(W + V_{\max}\right)}{V_{\max}} - W \ (1)$$

$$G_0 = \frac{G_i \times \left(W + V_{\max}\right)}{V_{\max}} - W \ (2)$$

$$B_0 = \frac{B_i \times \left(W + V_{\max}\right)}{V_{\max}} - W \ (3)$$

Where formula (1) $V_{\max} = MAX\left\{R_i, G_i, B_i\right\}, V_{\min} = MIN\left\{R_i, G_i, B_i\right\}$.The value of W is divided into the following cases:

$$W = V_{\min} \ (4)$$

$$W = V_{\min}{}^2 \ (5)$$

$$W = V_{\min}{}^3 + V_{\min}{}^2 + V_{\min} \ (6)$$

$$W = \frac{V_{\min} \times V_{\max}}{V_{\max} - V_{\min}} \quad \frac{V_{\min}{}^2}{V_{\max}{}^2} < 0.5 \qquad (7)$$

$$W = V_{\min}^{2} \quad \frac{V_{\min}^{2}}{V_{\max}^{2}} \geq 0.5 \tag{8}$$

Figure 6 is a schematic diagram of the algorithm.

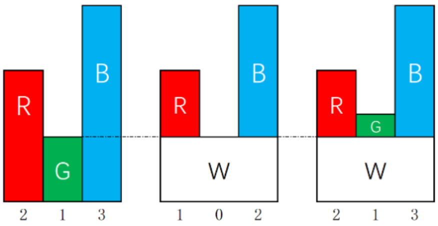


Figure 6: Algorithm diagram

The traditional algorithm has a small amount of computation but has obvious defects [18]. The calculation of the white component is only for the brightness, but cannot adjust the key saturation. If the component of one pixel is zero, for example, a pure red image will cause the white component is zero, and the improvement of brightness is limited [19-20], and the algorithm cannot compensate for the decrease in saturation caused by white pixels.

3.2. Improved RGBWY mapping algorithm (1)

Compared to the RGBW mapping algorithm, the new algorithm introduces the saturation parameter (S). The saturation responses the degree of vividness of picture, which the core idea is to control the white component size by saturation. The higher the saturation, the smaller the white component, and the lower the saturation, the larger the white component. The white component can be mixed by equal proportion of R, G, and B, and the yellow component can be mixed by equal proportion of R, G, so only R and G need to subtract the yellow component, and B does not need to be subtracted. In order to ensure that the R, G, and B ratios before and after mapping are constant, the following formula is used:

$$R_0 = \frac{R_i \times (W + V_{\max} + Y)}{V_{\max}} - W - Y \tag{9}$$

$$G_0 = \frac{G_i \times (W + V_{\max} + Y)}{V_{\max}} - W - Y \tag{10}$$

$$B_0 = \frac{B_i \times (W + V_{\max} + Y)}{V_{\max}} - W \tag{11}$$

That is:

$$R_i : G_i : B_i = (R_0 + W + Y) : (G_0 + W + Y) : (B_0 + W) \tag{12}$$

It can be known from formula (12) that the ratio of the three components of R, G, and B after signal mapping is the same as the ratio of the three components of the original image R, G, and B. Therefore, the saturation is not lost from the algorithm stage.

If the white component W=Vmin, Y=Vmin is directly set, this will take away a large number of colors from the R, G, and B components, causing a serious drop in saturation. In order to solve this problem, a new variable S is introduced.

$$S = \frac{V_{\max} - V_{\min}}{V_{\max}} \tag{13}$$

$$W = Y = (1 - S) * V_{\min} \tag{14}$$

The saturation S indicates the color change of the unit pixel combination. The larger the saturation S, the higher the pure color of the picture, and the smaller the relative white component and the yellow component. Although the algorithm can adjust the size of the white component and the yellow component according to the saturation, when the single pixel component is zero, the saturation is 100%, and the calculated white component and yellow component are zero.

3.3. Improved RGBWY mapping algorithm (2)

For the problem in Algorithm 1, three cases are introduced for saturation. Case 1: When the saturations S1 and S2 of the adjacent two groups of RGB are both greater than 1/2, the picture is considered to be a continuous high saturation condition. Case 2: When the saturations S1 and S2 of the adjacent two groups of RGB are less than 1/2, the picture is considered to be a continuous low saturation condition. Case 3: When one of the two sets of RGB saturations S1 and S2 is less than 1/2 and one is greater than 1/2, the picture is considered to be a junction of high saturation and low saturation.

Case 1: In the face of continuous high saturation, the yellow pixel component should be reduced. Increase the white pixel component to improve image brightness and transparency. At this time, $Y = (1 - S) * V_{\min}$, in the case of extremely high saturation, in order to ensure that the color does not overflow, the yellow component is allowed to be zero. $W = MAX\{R_i, G_i, B_i\}$, take the maximum of the three component.

Case 2: In the face of continuous low saturation, the yellow pixel component should be increased to compensate for the white pixel encroachment. Appropriately reduce the white pixel component to maintain saturation. At this time, $Y = MAX\{R_i, G_i, B_i\}$, $W = (1 - S) * V_{\min}$,in order to ensure that the white component is not zero. When a component is zero, the white component takes the minimum of the other two non-zero component.

Case 3: In the face of the junction of high saturation and low saturation, the yellow pixel and white component are both zero.

4. Simulation and results analysis

This article uses 512*512 Lena images for simulation. Since the market does not have RGBWY arrangement for finished screens, in order to verify the feasibility of pixel arrangement and mapping algorithms. The yellow component is proportionally mixed by the red component and the green component, and the yellow component is equally divided into a red component and a green component for comparison. Similarly, the white component in the RGBW algorithm is equally divided into RGB components. This ensures that RGB, RGBW, and RGBWY can be simulated by the RGB system. R, G, and B are separated from the image, and the saturation distribution image is drawn. The distribution image of the white component and the yellow component are compared, and the actual component sizes of the respective regions are observed. Finally, the peak signal-to-noise ratio (PSNR) and HSV model are calculated for the image, and the algorithm is evaluated by combining subjective and objective methods. Figure 7 shows the comparison of the results of each algorithm obtained by the experiment. (a) is the effect diagram of the original image. (b) is the effect diagram of the traditional RGBW algorithm, it can be seen that the overall picture is reddish due to the excessive white component. (c) is the RGBWY algorithm (1) effect diagram, the picture color is almost the same as the original picture. (d) is the RGBWY algorithm (2) effect diagram, the overall picture is bright, the color is not significantly offset.

Figure 7(a): Original image

Figure 7(b): Traditional RGBW algorithm

Figure 7(c): RGBWY algorithm (1)

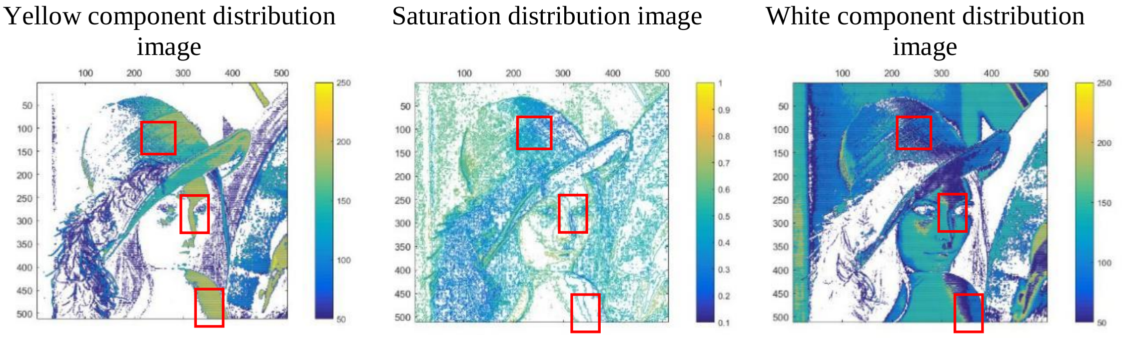
Figure 7(d): RGBWY algorithm (2)

The peak signal-to-noise ratio (PSNR) is used to more intuitively illustrate the effects of the new algorithm, usually used for contrasting with image compression and the original image. In this paper, matlab is used to calculate PSNR. The three algorithms are shown in Table 1.

Table 1: PSNR comparison

	Composite image	R	G	B
RGBW	19.3740	20.1032	17.6192	20.8026
RGBWY(1)	23.3674	23.0726	22.9084	22.9936
RGBWY(2)	15.2180	14.5041	15.8345	14.8763

The PSNR of the RGBWY algorithm (1) is superior to the other two algorithms in the R, G, and B components. The RGBWY algorithm (2) brings higher brightness and saturation to the picture, but the image quality is slightly degraded. The saturation, yellow component, and white component distribution of the RGBWY algorithm (2) are shown in Fig. 8. The continuous low saturation region is shown by the red square, the yellow component is larger and continuous, and the white component is relatively smaller. The yellow component of the continuous high saturation region has a large area of zero, and the white pixel is only zero at the junction of high saturation and low saturation due to algorithm protection. Experiments show that the RGBWY algorithm (2) can make corresponding changes according to the saturation change, so that the saturation of the composite image is the same as the original image saturation, and the image supersaturation does not occur.


Yellow component distribution image

Saturation distribution image

White component distribution image

Figure 8: Yellow component distribution

As shown in Table 2, the saturation mean of the traditional RGBW algorithm is significantly lower than the original image. The RGBWY algorithm (1) can increase the saturation by 10% compared to the original image, and can increase the saturation by 40% compared to the RGBW algorithm. The RGBWY algorithm (2) is more accurate in restoring the original image saturation.

Table2: Saturation comparison

	original image	RGBW	RGBWY (1)	RGBWY(2)
average value	0.4918	0.3848	0.5421	0.4346
Standard deviation	0.1362	0.1398	0.1548	0.1777

5. Conclusion

In this paper, the RGBW arrangement and the defects of its mapping algorithm are analyzed. A new RGBWY arrangement and two mapping algorithms are proposed.The RGBWY arrangement can effectively suppress the color encroachment of white pixels to surrounding pixels.The RGBWY algorithm (1) has a 40% improvement in saturation compared to the RGBW algorithm. Although the brightness enhancement is the same as the RGBW algorithm, the original picture is better restored.The RGBWY algorithm (2) can adjust the yellow component and the white component according to the saturation change. Compared with the RGBW algorithm, the original image saturation is more accurately restored, and the brightness is significantly improved. In the case of practical applications, different mapping algorithms can be used for different lighting conditions.Use the RGBWY algorithm (1) in a low-brightness environment for better image quality.Higher brightness is obtained using the RGBWY algorithm (2) in a brighter environment.

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