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Color Overlapping Method for Projection Systems Based on Light-Emitting Diodes

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Abstract

A color overlapping method for increasing the brightness of projection systems using light-emitting diodes (LEDs) is proposed. The proposed approach drives the pulse width modulated signals of red, green, and blue LEDs. This color overlapping method synthesizes secondary colors of yellow and cyan from primary colors of red, green, and blue. By the proposed method, the brightness of the projected image is improved by about 30% compared to the conventional non-color-overlapping method in a projection system with LEDs.

Keywords: *projection system, light-emitting diode, color overlapping, secondary color*

1. Introduction

The light-emitting diode (LED) shows well-known advantages for portable projection systems. It provides a solid-state light source. It is also is compact, reliable, and does not require the use of mercury. Moreover, its lifetime is longer than that of a standard lamp light source. Therefore, the LED is very environmentally friendly. Recently, the development of high-brightness LEDs has resulted in LEDs being adopted as the lighting sources of projection systems [1-7].

Technically, an LED is designed to operate with a forward driving current under both the continuous waveform driving method and the pulse width modulation (PWM) driving method [1]. Figure 1 shows the brightness and efficiency characteristics of typical LEDs. It is noted that the brightness is not proportional to the current and the efficiency decreases as the current increases. This problem becomes serious when an LED is used for a projection system, where the LED is used in the very high current mode [2-3].

In this paper, the design of a new LED driving method is proposed. Whereas traditional driving methods use red (R), green (G), and blue (B) colors [3-5], the proposed driving method uses R, G, B, yellow (Y), and cyan (C) colors, as shown in Figure 2. The driving efficiency of the LEDs is improved by increasing the duty ratio of the secondary colors (Y, C, and magenta (M)). In Section 2, the proposed method is described. Experimental results and conclusions are given in Sections 3 and 4, respectively.

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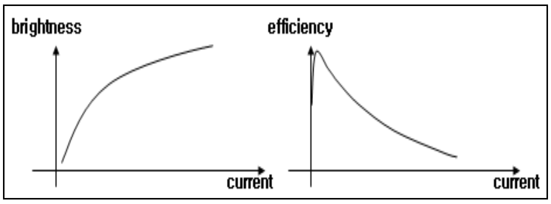

Figure 1. LED Brightness and Efficiency Characteristics

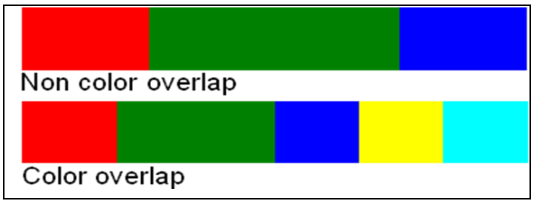

Figure 2. Colors Used by Traditional Non-Overlapping Methods and our Color Overlapping Method

2. Proposed Method

A color overlapping method is proposed for providing more efficient and higher-brightness illumination than conventional LED projection systems in which the colors do not overlap. The driving efficiency of the LEDs is improved by increasing the duty ratio of the secondary colors (such as Y and C) obtained from color synthesis between the primary colors (R, G, and B).

In Figure 3, the driving pulse wave of the LEDs (R, G, and B) is shown. Y is produced from R and G by synthesis. C is produced from G and B by synthesis. Each frame is composed of a sequence of several colors and the color sequence consists of primary and secondary colors. For instance, when one frame (of duration 1/60 Hz = 16.67 ms) is composed of a sequence of five colors, as shown in Figure 3, the available timeslot for each color in the sequence is 3.33 ms. The percentage of this 3.33 ms that consists of a secondary color is called the overlap duty ratio.

Several possible examples of the proposed color overlapping are shown in Figure 4. The brightness (in ANSI lumens) of the projector with increasing duty ratio of the generated secondary colors (Y, C, and M) for the frames at a frequency of 60 Hz is measured, and the optimal combination is found, as described in Section 3. It is noted that, due to the limits of the frame frequency, the duty ratio of the primary color decreases as the duty ratio of the secondary color generated from primary color synthesis increases. This may cause the result of bad color linearity. Therefore, the secondary color ratio is a very important factor in image quality.

3. Experimental Results

To find the optimal combination of overlapping primary colors among all the combinations, experimental results of brightness measurements (in ANSI lumens) for four cases are shown: Y; Y and C; Y and M; Y, C, and M. It is noted that our experiments for all the combinations have shown that one of these cases shows the best result of all the combinations. Figure 5 shows the results. It is shown that the proposed color overlapping method increases the brightness very well. It is also shown that the brightness increases with the color overlap duty ratio. For the color overlap duty ratio up to 45%, the brightness increase ranges up to 30%. When the color overlap duty is fixed, the maximum increase in brightness among all possible color overlapping combinations is obtained from the YC overlap.

Figure 6 shows the total power consumption of each of the color overlapping methods. As shown, the YC overlap demands the highest current. However, compared to the increasing rate of brightness, the current increasing rate of YC overlapping is known to be limited. Hence, it is concluded that the YC overlap is the most efficient way to increase the brightness among all the color overlapping combinations.

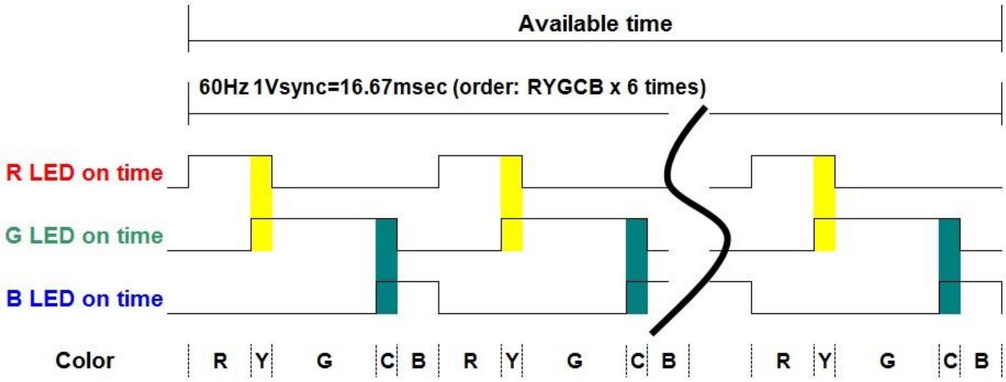

Figure 3. Waveform of Primary Color Overlapping Scheme

	Red LED on time (Duty)	Green LED on time (Duty)	Blue LED on time (Duty)	Remark
No color overlap	Red Duty	Green Duty	Blue Duty	Seconadry color Duty (Y,C,M,W) : 0~45%
Overlap Yellow	Duty = Red Duty + Yellow Duty	Duty = Green Duty + Yellow Duty	Blue Duty	
Overlap Yellow & Cyan	Duty = Red Duty + Yellow Duty	Duty = Green Duty + Yellow Duty + Cyan Duty	Duty = Blue Duty + Cyan Duty	
Overlap Yellow & Magenta	Duty = Red Duty + Yellow Duty + Magenta Duty	Duty = Green Duty + Yellow Duty	Duty = Blue Duty + Magenta Duty	
Overlap Yellow & Cyan & Magenta	Duty = Red Duty + Yellow Duty + Magenta Duty	Duty = Green Duty + Yellow Duty + Cyan Duty	Duty = Blue Duty + Cyan Duty + Magenta duty	
Overlap Cyan	Red Duty	Duty = Green Duty + Cyan Duty	Duty = Blue Duty + Cyan Duty	
Overlap White	Duty = Red Duty + White Duty	Duty = Green Duty + White Duty	Duty = Blue Duty + White Duty	

Figure 4. Examples of Overlapping Primary Colors

4. Conclusion

This paper proposes a high-brightness LED projection system that uses secondary color overlapping. It has been shown that the secondary colors (Y, C, and M) may increase the efficiency of LEDs in a high-brightness projection system that is compact and has low power consumption, which demonstrates the merits of this projector design. This method improves brightness by 30% when the color overlap is composed of R, G, B, Y, and C sequential colors.

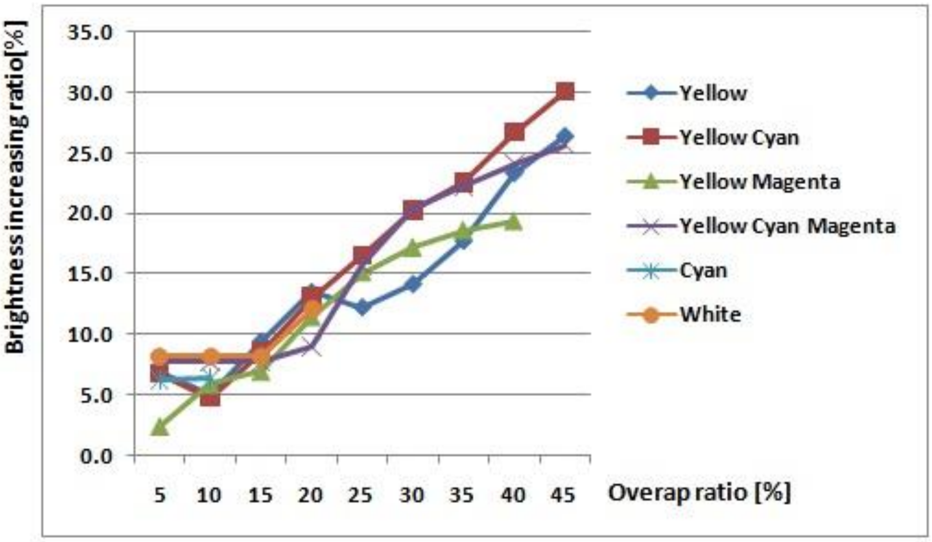

Figure 5. Brightness Increase versus Color Overlap Ratio

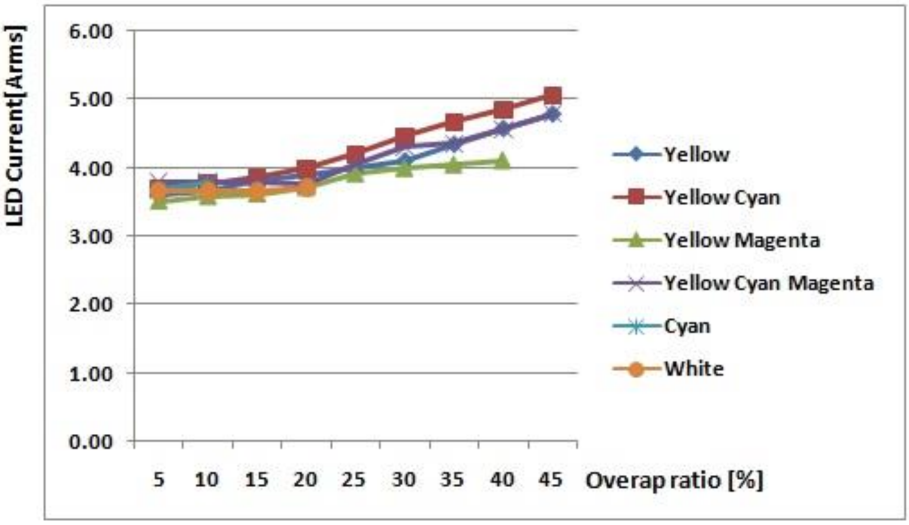

Figure 6. Power Consumption of Overlap Types

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