Improving Power Efficiency for Color OLED Display using Color Difference Algorithm

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Abstract

The power efficiency of a full-color OLED display decreases with long-term operation because of the material characteristics. The lifetime of the OLED display also decreases as the power efficiency declines. Therefore, this work provides a novel color difference algorithm to improve the power consumption and extend the OLED lifetime.

1. Introduction

Active-matrix organic light-emitting diode (AMOLED) has attracted much attention because of its favorable characteristics, such as wide viewing angle, fast response and high power efficiency. Although the OLED has high power efficiency, its power efficiency and lifetime gradually decreases with long-term operation [1]. Although OLED has high power efficiency, the power efficiency and lifetime of OLED gradually decreases with long time operation [1]. Nowadays, the lifetime of an OLED with blue emission is shorter than that with red or green emission [2]. Additionally, according to the theory of the human vision, the number of R receptors is slightly more than green ones, and there have much less blue receptors compared with red and green ones [3]. Thus, to increase the lifetime of OLED displays, this work develops a new method which involves only slight distortion visible to the human eye to improve the power efficiency of the display [4].

In this paper, this work improves the power efficiency of full color OLED display, especially in blue emission of OLED, by CIE color difference algorithm. The power efficiency of the full color OLED display is increased and the life time of sub-pixels, R, G and B, particularly in B, is also extended. Additionally, the full color OLED display still has the almost same image quality for our eyes. The simulation of our proposal by CIE color difference algorithm revels that the power efficiency of full color OLED display efficiently increases and the lifetimes of sub-pixels in the OLED display can be lengthened.

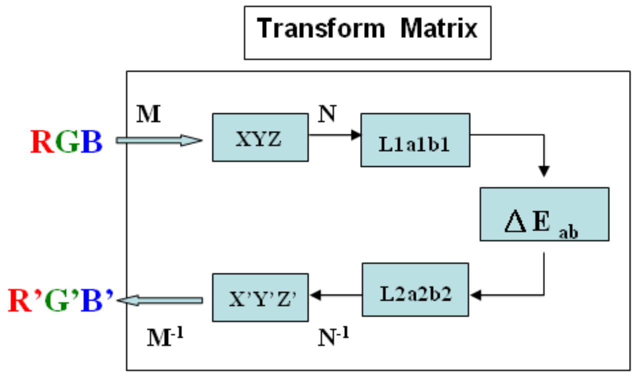


Fig. 1. Flow chart of the proposed transformation by CIE color algorithm.

2. Algorithm design

Fig.1 shows the flow chart of the proposed transformation by CIE color algorithm based on the color transformation from CIE1976. The original gray level values R, G, and B of the sub-pixels are transformed to the CIEXYZ tristimulus values (X, Y, Z), which are then transformed to the CIE$L^*a^*b^*$ color triplets (L_1, a_1, b_1). The transformation matrix of the color space from (R, G, B) to (X, Y, Z) is as follows.

$$[X\,Y\,Z]=[R\,G\,B]\begin{bmatrix}0.412424 & 0.212656 & 0.0193324\\ 0.357579 & 0.715158 & 0.1191930\\ 0.180464 & 0.072186 & 0.9504440\end{bmatrix} \quad (1)$$

Additionally, CIE$L^*a^*b^*$ color triplets (L^*, a^*, b^*) are a nonlinear transformation of CIEXYZ tristimulus values (X, Y, Z) and are used to construct a perceptually uniform color space

$$\begin{cases} L^* = 116(Y/Y_0)^{1/3} - 16 & (Y/Y_0 > 0.00885) \\ a^* = 500\left[(X/X_0)^{1/3} - (Y/Y_0)^{1/3}\right] \\ b^* = 200\left[(Y/Y_0)^{1/3} - (Z/Z_0)^{1/3}\right] \end{cases} \quad (2)$$

where the tritimulus (X_0, Y_0, Z_0) are reference value observed under the white point [5] [6]. The variable L^* represents the brightness information. The factor a^* and b^* include the gray level variations. The color difference (△Eab) between two colors (L_1, a_1, b_1) and (L_2, a_2, b_2) is defined as follows

$$\begin{aligned} \Delta L &= L_2 - L_1 \\ \Delta a &= a_2 - a_1 \\ \Delta b &= b_2 - b_1 \\ \Delta E_{ab} &= \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \end{aligned} \quad (3)$$

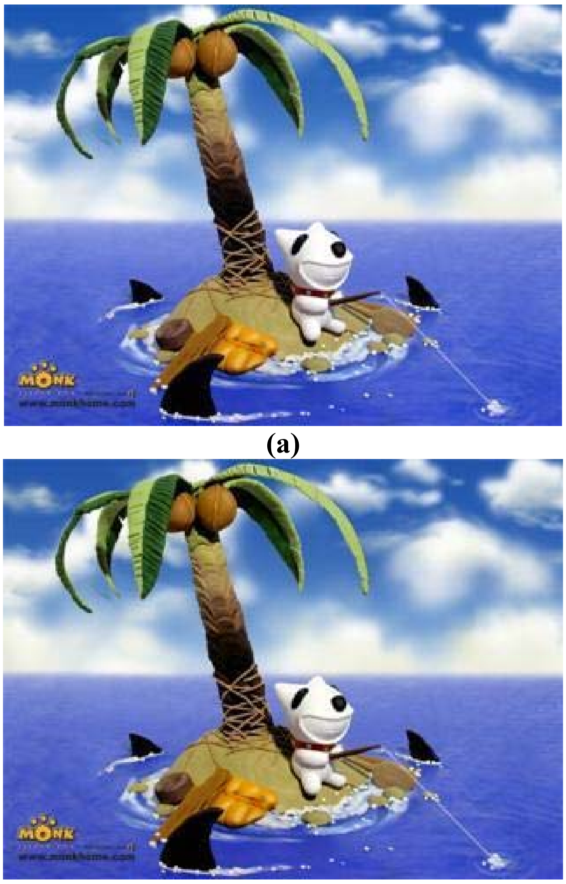
Furthermore, in the nonjudgmental range of color difference equation (△Eab) for our human vision, we find the individually optimum value and the fixed tolerable color difference (△Eab) for the human vision. From (3), the transformed (L_1, a_1, b_1) is recalculated to yield the new (L_2, a_2, b_2) by the optimum values

$$\begin{aligned} L_2 &= L_1 + C1 \\ a_2 &= a_1 + C2 \\ b_2 &= b_1 + C3 \end{aligned} \quad (4)$$

where (L_1, a_1, b_1) and (L_2, a_2, b_2) are the CIELAB colors of the original image and the proposed image, respectively. The coefficients (C1, C2, C3) are the optimal values, leading to difficulty of recognition by the human vision [6]. Equation (4) shows the relationship between the CIELAB color of the original image and that of the proposed image. Consequently, through the inverse transformation, the new gray level value R', G' and B' sub-pixels are obtained and the regenerated gray level values (R', G', B') are individually smaller than the original gray level values (R, G, B) of the sub-pixels. Thus, the regenerated images of the full color OLED display are individually determined by the R', G' and B' value.

3. Results and discussion

Fig. 2 shows that the image quality has the hardly distortion between the original image and the regenerated image. According to the proposed color difference algorithm, the color difference value (△Eab) between the regenerated image and the original image is in the unnoticeable range of human vision.



(a)

(b)

Fig. 2. (a) Original image (b) Regenerated image

Fig. 3 shows the simulation of the power consumption between the original image and the regenerated image. The power consumption data of each gray level value of R, G and B emission OLED are provided from AUO. The simulation results exhibit that the distribution of the gray level values of the R, G and B sub-pixels between the original image and regenerated image, and the total power consumption of our proposed image is lower than that of the original image. Additionally, the total power of the B sub-pixel in the regenerated image is efficiently lower than that in the original image and the distortion between the original image and the regenerated image is negligible. By reducing the total power consumption of the image and of the B sub-pixel, the lifetime of R, G, and B emission OLED, especially in B emission OLED, can be efficiently extended.

Fig. 4 shows the power consumption of the other images for the original RGB and regenerated RGB

AMOLED displays. On average, the decreased ratio of the total power consumption with our proposed method by CIE color difference algorithm is about from 5% to 10%. Due to the decreased total power consumption, the lifetime of the AMOLED display can be efficiently stretched.

4. Conclusion

This work improves the power efficiency of AMOLED displays by using color difference algorithm and the lifetimes of R, G and B emission OLED are extended. Besides, the image quality of our proposal is in hardly distortion. This proposal will provide considerable benefits to large AMOLED displays in the future.

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6. References

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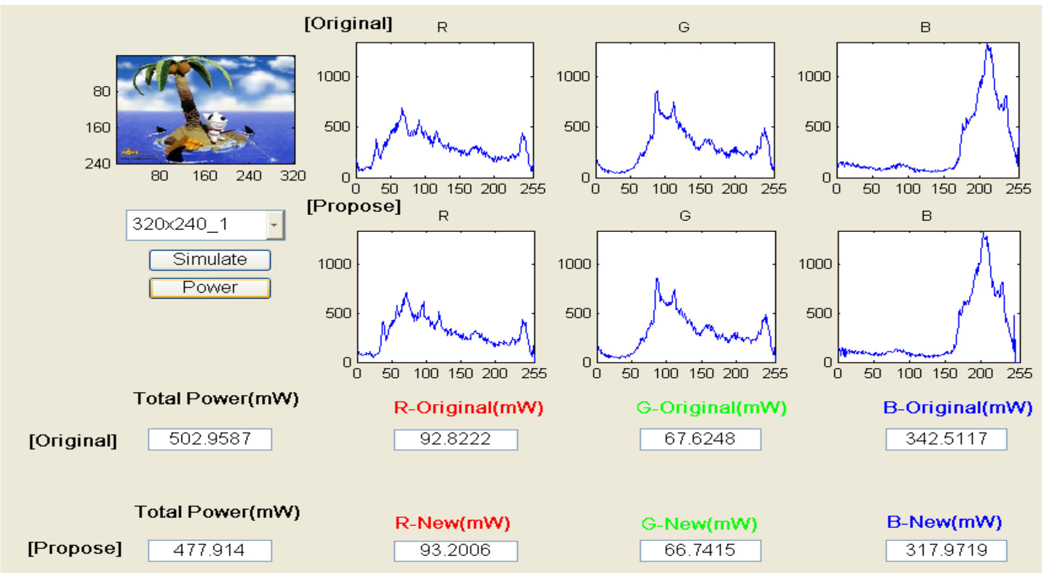

Fig. 3. Power consumption between the original image and the regenerated image.

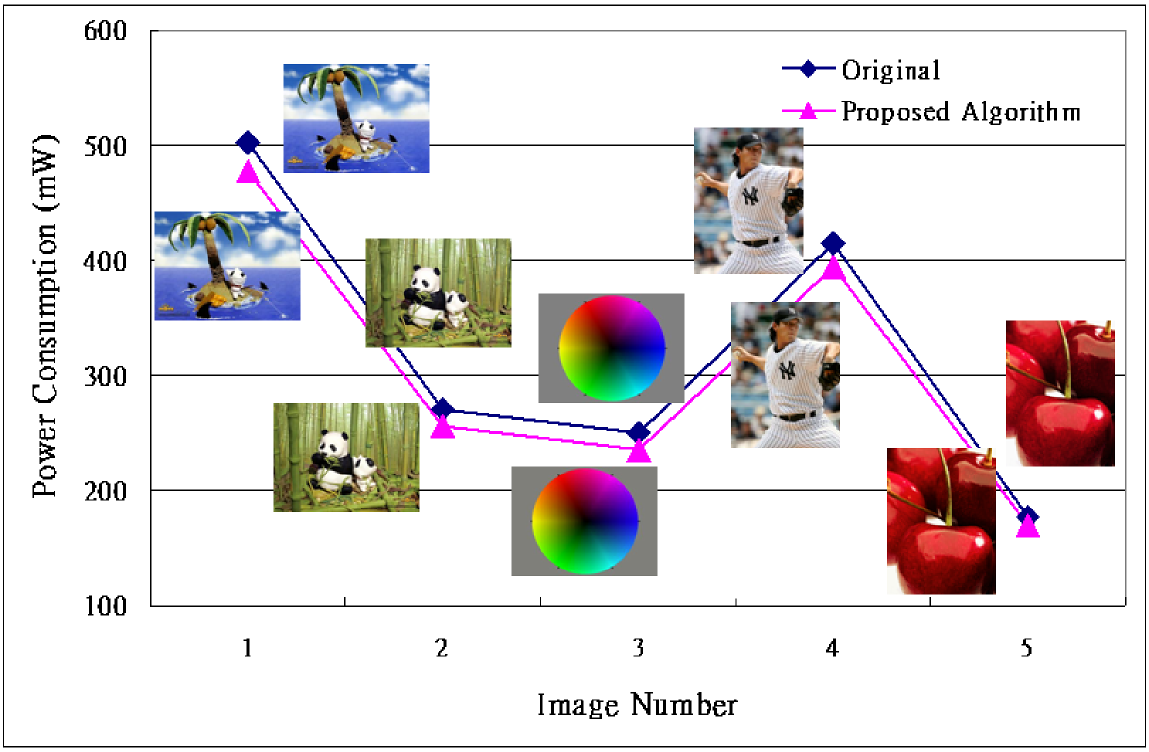

Fig. 4. Power consumption comparison of the other images.