High Efficient FSC LCD using Color Break-up Reduction and Compensation

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FSC LCD 에서의 컬러 분리 저감 및 화질 보상 기술

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요 약

(Abstract) FSC(Field Sequential Color) LCD has high efficiency, high brightness and color saturation due to 3 times aperture larger than conventional LCD. However it is well known that color break-up (CBU) and color interference are hot issue need to be solved. We propose a novel sequential driving method with edge-lit light guide composed of 16x15 blocks to reduce CBU and color interference. The experimental results show not only suppression of CBU but also the side effects are minimized.

1. INTRODUCTION

LCDs are greatly used in our daily display devices because they process several advantages, such as high resolution, high brightness, and thin structure. However it has low optical throughput. Using polarizes and color filter results in approximately only 5% ~ 10% of optical throughput on the front screen[1]. Since FSC LCD has not color filters, RGB LEDs should be used sequentially instead of white LEDs to represent colors. So each color components are received separately by retina.

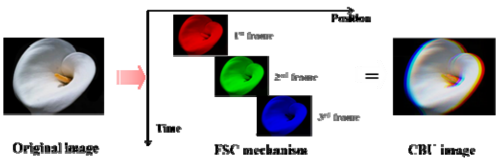

Fig.1. Field Sequential Color mechanism and Color Break-Up(CBU)

When relative velocity exist between screen object and viewer's eyes, a visual artifact called Color Break-Up(CBU) is emerged[2] as shown in Figure 1. Most CBU suppressing method doesn't make remarkable results because it is caused by serious color difference between frames[3].

In this paper, we propose a primary color decision method with local dimming technology which can find the minimum color difference for a block area in each frame. This application makes it possible to drive 240Hz FSC LCDs in commercial panel without CBU.

2. ENHANCED METHODS

The number of backlight blocks, frame rates and backlight sequence affect CBU. If there are many blocks of backlight, color dispersion becomes smaller between blocks and the probability of CBU is decreased.

Figure 2 shows color area of backlight according to the number of blocks. To reduce color difference, divided blocks are more effective than full screen in primary color decision. FSC system needs more BL driver-IC as the number of blocks which are limited by frame rate until 240Hz.

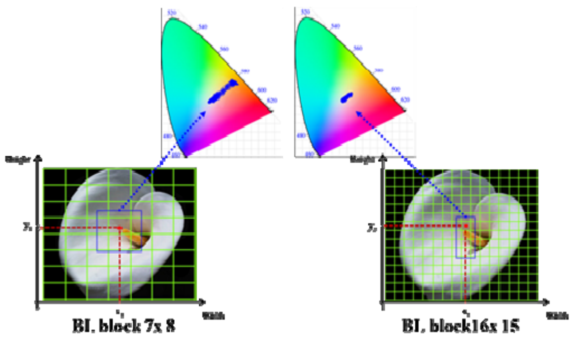

Fig. 2. Backlight color area according to the number of blocks.

We decide 16x15 color areas of BLU considering of the primary colors in divided blocks.

First we decide D4 frame which is the brightest part in image and D1, D2, D3 frames are decided considering minimum color cluster in the triangle area as shown in

Figure 3.

If original image is brighter, CBU is visible more easily. Then we determine primary colors by brightness value and extract dominant color through R/G/B data. In primary color extraction, Input image data are transferred from R, G, B to tri-stimulus values in the CIEXYZ color space as target signal. The generated BLU data is converted to PWM data and is transmitted to BLU controller. Primary color is used at color reconstruction.

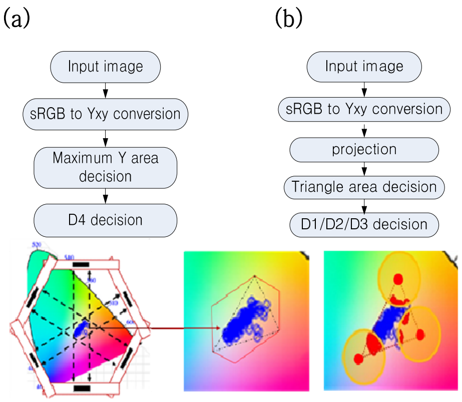

Fig. 3. D4 decision and and D1, D2, D3 decision in local primary color decision method

After we decide D4 frame though Y domain, D1, D2, D3 frames are decided. We find cluster shape from converted XYZ and project a shadow on 3-axis(0°, 120°, 240°). Then triangle area is decided through hexagon shape and each vertex is selected as primary color. Because it presents minimum color difference, CBU can be reduced.

In order to evaluate, we try to compare genetic algorithm. In entire pixels region, we simulate how many non CBU regions and brightest region is found with 5 images. We find result that not only shape but also distribution of pixels is considered. Comparing result is illustrated in table 1. Equation 1 is parameter of CBU ratio in proposed algorithm.

The more is good in non CBU pixel ratio. The fewer is good in CBU pixel brightness.

$$NonCBU\ pixel\ ratio = \frac{number\ of\ pixel\ in\ NonCBU\ area}{all\ pixels}$$

$$CBU\ pixel\ brightness = \frac{sum\ of\ brightness\ in\ outside\ nonCBU\ area}{number\ of\ pixel\ in\ outside\ nonCBU\ area}$$

Most CBU is suppressed through local primary color decision. However many artifacts is emerged due to slow LC response time. Phenomenon that they are called “ block leakage and frame leakage” comes out on screen. This artifacts change colors and distort original image. Then we suggest method that minimizes LC data variation. As LC data changes, also BL color is changed.

Table.1. Comparison with genetic algorithm

image	Proposed algorithm		Genetic algorithm	
	Non CBU pixel ratio	CBU pixel brightness	Non CBU pixel ratio	CBU pixel brightness
	18.6%	8.85	4.3%	6.93
	34.8%	29.42	4.5%	25.5
	37.5%	15.6	14.0%	10.84
	17.6%	24.43	13.8%	18.7
	86.0%	16.7	91.7%	15.3

3. ARTIFACTS AND SOLUTION

When we use local primary color decision, if only it is used, other side effects occur. Due to slow response, it is emerged color that we don’t want and the image is broken.

It is block artifact. In figure 5, we find that background color is different between two blocks. At each block, if it represents only defined BL color, distorted colors are emerged because of difference between frames. Then block boundary is shown and wrong color is represented. Cause is the slow response of the LC(Liquid Crystal). If we represent dark blue, interference occur in D2/D3 frame colors as shown in figure 5. As a result, not intended color is emerged. To compensate block artifact, at each blocks, it make similar color using LC data and BL brightness change. In figure 6, it is shown result that background color is almost same. D1 LC data decrease and D3/D4 LC data increase. Through reducing difference of LC data, we minimize light leakage. Lack of D1 brightness is compensated through D3/D4 frame. So background color is represented and also other colors are emerged exactly. It is important that how image is analyzed at each block. LC data acquisition and BL color brightness decision has different result at each frame and image in real time.

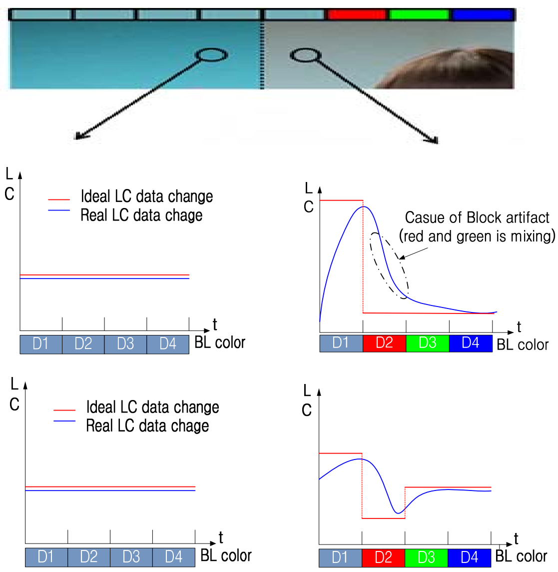

Fig. 5. Reduced block artifact result

4. SYSTEM AND RESULT

We make FSC 65” system with 16x15 blocks BLU and it change BL color as original image in real time. Figure 9 is internal composition of block BLU. Figure 10 is real image. And figure 10 is backlight image. We make comparison between R/G/B/K and Local Primary Decision (D1/D2/D3/D4). In figure 10, Left side is R/G/B/K and right side is local primary decision (D1/D2/D3/D4) in a screen. In case of local primary decision, upper side is bluish color due to sky, and lower side is greenish color due to grassland in figure 11. As a result, CBU is reduced practically. It is almost like to original image. It is invisible that other artifact is emerged.

Difference that compare between conventional FSC and local primary color decision method is shown in figure 12. We show original image and image that algorithm is applied to 40 persons. And we ask to person whether or not difference between two images. JND (Just Noticeable Difference) are calculated. JND is different according to image’s feature. But acquired data is JND2 at several images. More than 55% of all persons don’t notice image difference.

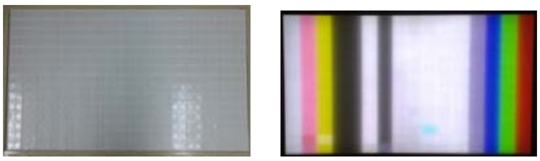

Fig. 6. 55” Slim BLU of 16 x 15 blocks: Turn Off/On

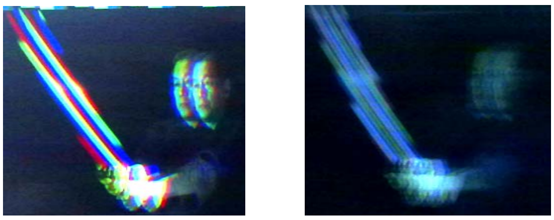

Fig.7. Evaluation Results : Left (R/G/B/K), Right (local primary color decision)

4. CONCLUSION

Critical issues of FSC LCDs are color break-up(CBU). In the experiments of the past, we found a way to remove CBU through the color algorithm rather than raising driving frequency. Then we develop local primary color decision algorithm and segmented backlight unit. It is significant that how we decide proper BL color and pixel data. It is important that we solve the artifact producing by algorithm. Comparing genetic algorithm, we verify performance. We find result that not only shape but also distribution of pixels is considered. So we reconstruct clear image considering artifact due to slow LC response. We reduce CBU through 240Hz (local primary color decision) and improve the color gamut using 16x15 blocks BLU.

As a result, we acquire much better JND. It can be reached at JND2. We will improve until JND1. And we try to quantify CBU. We think that proposed technology can be commercialized perfectly in the DID (Digital Information Display). FSC LCDs technology is expected to be applied in Echo display.

References

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