A novel LED display architecture using 4 color sub-pixel rendering

Dae-Sik kim, Tetsuya Shigeta, Sang-Kyun Im and Ho-Sup Lee

Samsung Electronics
daesikkim@samsung.com, tets.shigeta@samsung.com, sky.im@samsung.com, hosup.lee@samsung.com

4 컬러 서브픽셀 렌더링 적용 고해상도 LED Display

Dae-Sik Kim, Tetsuya Shigeta, Sang-Kyun Im and Ho-Sup Lee
Samsung Electronics

요 약

(Abstract) We have developed a novel LED display architecture with RGGB 4sub-pixels rendering. LED light control filter algorithm is proposed in order to reduce color fringes by sub-pixel rendering which is a method of perceptual enhancement. The results show that it has 2 times higher perceptual resolution without artifacts.

1. INTRODUCTION

The large area LED displays are widely used as outdoor display for showing advertisement and some information, and are spreading to use as indoor display. But it is limited to increase resolution due to a size of packaged LED chips.

Some sub-pixel rendering methods had been proposed to improve resolution compare to conventional 3-prime-color-1-pixle structure. The structure of these are normal 3 prime color sub-pixel, adding one of prime color to 3 prime color, adding different color to 3 prime color, adding white sub-pixel to 3 prime color, and so on. In any structure, sub-pixel rendering method causes annoying artifact. It’ s a sight of false color on high space frequency image like as high contrast edge, called color fringe artifact generally.

Some methods for improvement of resolution are proposed as a new LED sub-pixel structure and sub-pixel rendering. And the methods reducing color fringe artifact on the edge image are also proposed. [1]

In this paper, we propose a new method of suppressing color fringe artifact with improve resolution for sub-pixel rendering in the Bayer matrix sub-pixel arrangement and evaluate perceptual resolution how higher than conventional sub-pixel arrangement with normal pixel rendering by new MTF simulation and displaying experiment.

2. PIXEL ARRANGEMENT AND RENDERING

The conventional LED Displays has pixel structure including only RGB 3 prime color. In order to improve resolution, some sub-pixel structures and some sub-pixel rendering methods are proposed. A sub-pixel rendering is displaying independent data in each sub-pixel. Our method is RGGB structure, called Bayer’ s matrix, with sub-pixel rendering. Figure.1 shows conventional and our sub-pixel structure and rendering way.

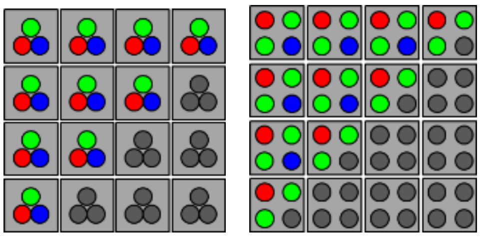

Fig.1. RGB sub-pixel structure with pixel rendering (left), RGGB sub-pixel structure with sub-pixel rendering (right)

3. COLOR FRINGE COMPENSATION

But the color fringe can be seen in high frequency image because of lack or weakness of other sub-pixel color.

We have developed the light control filter algorithm adapted the characteristics of LED displays which are sharp spectrum of each color LED and low fill factor of sub-pixel area. It aims both improvement of resolution and reduction of color fringe artifact. It is a 7x7 2-D matrix filter that is changed parameter by two type of sub-pixel color(G and

R/B) and direction of edge(positive and negative) in image as below equations. A general 3x3 HPF is available to detect the direction. If the data exceeds maximum value in this process, it is limited to maximum. Figure.2 shows PSF (Point Spread Function) of each matrix filters which have characteristic of circular symmetry.

$$S_{out}(x,y) = H(x,y) * s_{in}(x,y)$$

$$H(x,y) = \begin{cases} H_{gp}(x,y) & Green, Positive\ edge \\ H_{gn}(x,y) & Green, Negative\ edge \\ H_{rbp}(x,y) & Red/Blue, Positive\ edge \\ H_{rbn}(x,y) & Red/Blue, Negative\ edge \end{cases}$$

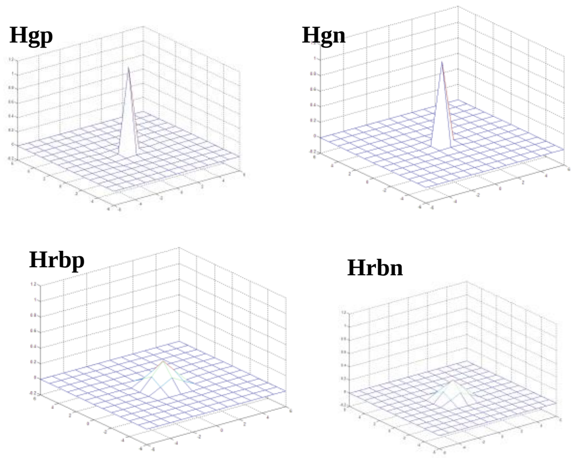

Fig. 2. Fig.2. PSF of each matrix filter

Table.1. PSNR of chrominance signal

	conventional DSR		novel Anti-aliasing Filter			
	PSNR(U)	PSNR(V)	PSNR(U)	Δ	PSNR(V)	Δ
Image1	29.21dB	29.95dB	32.53dB	3.32dB	32.76dB	2.81dB
Image2	28.98dB	29.25dB	31.65dB	2.67dB	31.46dB	2.21dB
Image3	26.75dB	27.36dB	30.17dB	3.43dB	30.23dB	2.87dB
Image4	31.26dB	31.63dB	34.24dB	2.98dB	33.90dB	2.27dB
Image5	29.33dB	30.43dB	33.00dB	3.67dB	33.48dB	3.05dB

The effect of this filter for reduction color distortion is evaluated by PSNR (Peak Signal to Noise Ratio). The PSNR of chrominance signal U and V are calculated for 5 images which being provided by Kodak. [2] Table.1 shows the result of two method comparison. Our color anti-aliasing filter method has about 3dB higher PSNR than non-filtered direct sub-pixel rendering (DSR) method. Figure.3 shows the result of image simulation. The color fringe artifact is disappeared on our filter method.

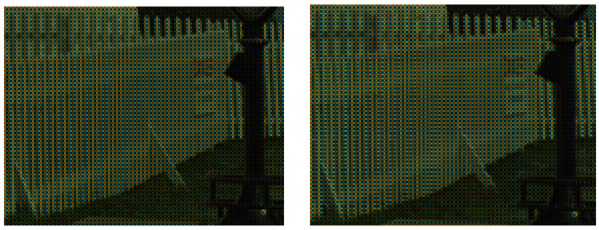

Fig.3. Simulated images for color fringe. Conventional direct sub-pixel rendering (left). Novel filtered sub-pixel rendering (right)

4. . PERCEPTUAL RESOLUTION

4.1 Evaluation of resolution by Calculation

It is evaluated by calculation how the method of RGGB structure with filtered sub-pixel rendering (RGGB-FSR) improve rather than RGB structure with normal pixel rendering (RGB-PR).
VESA defines measurement of resolution from contrast modulation using black and white lines. It is applied for normal pixel rendering, and it is not defined for sub-pixel rendering. After we calculated a resolution for our RGGB-FSR by VESA' s definition, it was higher than actual perceptual resolution even though using threshold as 50% for text and graphics images.

Therefore, we propose a new evaluation way to compare the perceptual resolution between normal pixel rendering and sub-pixel rendering. It uses MTF (Modulation Transfer Function) comparison. MTF is amplitude response for sine wave. In our evaluation, MTF is defined as function how an analog image in the natural world can be represented, so it calculated amplitude response for analog sine wave input.

$$s_{\omega} = \frac{A_{in}}{2}\{\sin(\omega t + \vartheta) + 1\}$$

$$MTF_{\omega} = \frac{|H(s_{\omega})|pp}{A_{in}}$$

$|\quad|pp : peak\ to\ peak\ in\ 1\ cycle$

Because there are any types of amplitude levels(A_in) and phases(Θ) in natural world, the average for these must be calculated. At first, the simple average MTF for phases that change from 0[deg] to 360[deg] is calculated for each amplitude level.
After that, the weighted average MTF for amplitude levels by the histogram of standard images.
Figure.4 shows the calculated MTFs for conventional RGB-PR and RGGB-FSR. In the case of RGB-PR, it can display maximum frequency 0.5[cycle/pixel] pattern with MTF 0.64. RGGB structure has MTF 0.64, same with RGB, at 0.72[cycle/pixel]. That frequency ratio is 0.72/ 0.5=1.44 that means the resolution is 1.44 times higher than RGB-PR. This result can be applied not only for horizontal

resolution, but also for vertical because this RGGB arrangement can be same sub−pixel arrangement even if it is rotated 90 degree.
Therefore, total resolution is〖 1.44〗 ^2=2.1 times higher than conventional.

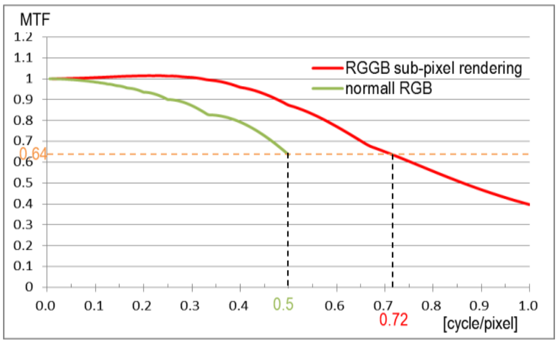

Fig.4. MTF for RGB with normal pixel rendering (green) and RGGB with filtered sub-pixel rendering (red)

4. 2 Evaluation of perceptual resolution by visual test

A subjective evaluation has been conducted. That is viewing test comparing between RGB−PR and RGGB−FSR Figure.5 shows displaying pattern and test conditions. Displaying pattern is a wedge pattern which has continuous change of sine wave frequency. The vertical and horizontal patterns are prepared for horizontal and vertical resolution test. A viewer must find the part in wedge pattern on RGGB display, that part is visible nearly equal to the part of Nyquist frequency in wedge pattern on RGB display. The frequency of selected part is converted normalized value by calculating pixel pitch ratio between two displays.
As a result, RGGB−FSR has about 1.4 times higher horizontal and vertical resolution than RGB−PR. Thus, the total resolution is about 2 times higher. The result is almost same with the evaluation calculated MTFs.

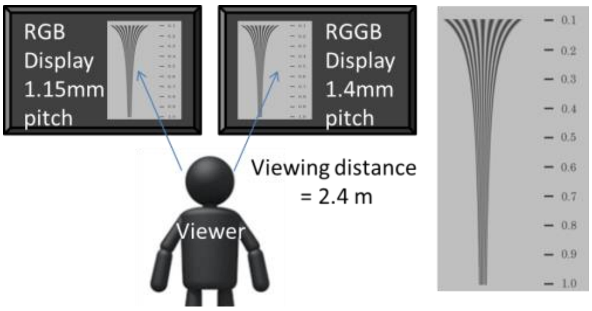

Fig.5. The way of practical evaluation and used wedge pattern

4. CONCLUSION

We have developed a new LED display that has RGGB sub−pixel structure with filtered sub−pixel rendering. The color fringe artifact has been reduced and perceptual resolution has been improved. It is sure to be about 2 times higher perceptual resolution than RGB structure with same pixel pitch. Thus, even if it is 1/ √2 pixel pitch, it is possible to produce same resolution displays. It cause 30% cost cutting due to reduction of LED chips.

References

[1] L. Fang, O. C. Au, K. Tang, and X. Wen Increasing image resolution on portable displays by subpixel rendering (APSIPA, 2012)

[2] Kodak Lossless True Color Image Suite http://r0k.us/graphics/kodak/ [3] A. Yoshida et al., in SID Symp. Dig. Tech. Papers, 2011, vol. 42, pp. 313- 316.