Measurement of Color Uniformity of Liquid Crystal Projection Display

Chen Ying, Li Haifeng, Shen Mo, Liu Xu, Shen Shizhe
State Key Laboratory of Modern Optical Instrumentation, Dept. of Optical Engineering
Zhejiang University No.38 Zheda Rd, Hangzhou, P.R.China
Phone: +86-571-87951187, E-mail: smilechenying@yahoo.com.cn

Abstract

A CCD-based color uniformity measurement system was set up. Through measuring the two-dimensional brightness distributions of three primary colors on the screen, chromaticity coordinate distributions of combination gray can be obtained within a few seconds. This system can be widely used in the production of LCD projection.

1. Introduction

At present, most color uniformity measurements of LCD projectors are done by the colorimeter[1], which can only detect one point at one time. The method that nine colorimeters are placed at different positions of the screen was offered. However, as the integrating devices, the cost of these colorimeters is high. Thus, the measurement with CCD is a good alternative. The advantage of using CCD is that the number of detectors for a single measurement can be very large[2]. Our monochrome CCD camera can capture a frame of picture, which provides the gray values of 573 x 720 pixels, in 1/25 second. With this CCD camera, one can achieve the chromaticity coordinate distributions of the screen rapidly.

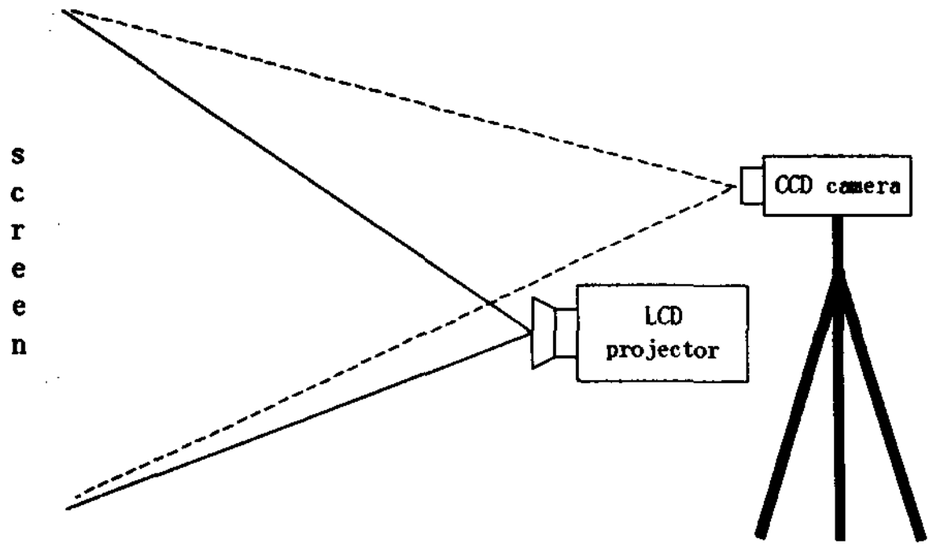

Figure 1: The measurement system

2. Experiment

As shown in figure 1, the measurement system comprises the LCD projector, CCD camera and the screen. In the experiment, the LCD projector is a 120W three-panel front projector. The CCD camera is a 10-bit high-accuracy monochrome CCD and it can capture two-dimensional gray value distributions of red, green and blue components of the combination gray individually by time-sharing. The LCD projector was in front of the screen and CCD camera was set in a proper position, where it can capture the whole picture. The whole system should be set in a dark room to avoid the effect of the ambient light.

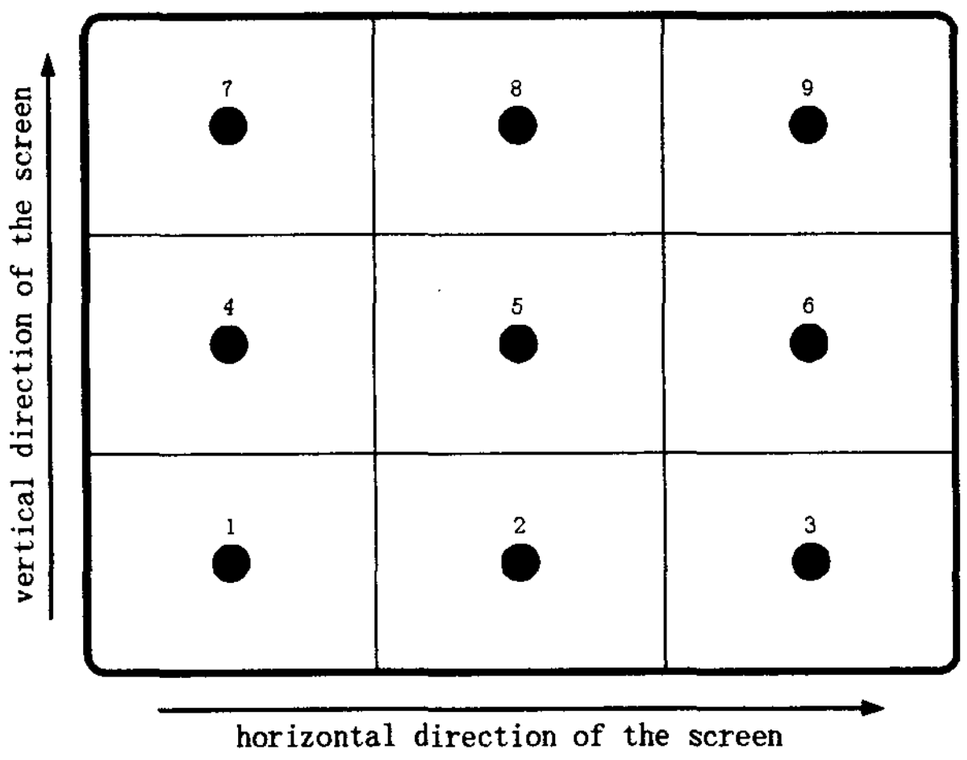

Figure 2: The diagrammatic sketch of nine zones

Before the measurement, the calibration of CCD camera is necessary. In the practical measurement, due to different chromaticity coordinate distributions at different gray levels, the measurement should be done at three gray levels: the high luminance gray level (250,250,250), the middle luminance gray level (150,150,150) and the low luminance gray level (50,50,50). Because of the different luminance non-uniformity at different gray levels and the different spectral response at different wavelengths of CCD camera, the experiment includes the measurement of the luminance---gray curves of nine different zones of the three primary colors at three gray levels, respectively. The diagrammatic sketch of nine zones is

shown as figure 2. The luminance---gray curves of the central zone of the screen of red, green, and blue are shown in figure 3, 4 and 5. In figure 3, 4 and 5, red, green and blue points express the luminance values of red, green and blue measured by the illuminometer, respectively. The black lines express the luminance-gray fitting curves captured by CCD.

With the luminance-gray fitting curves of nine zones and the gray value distributions captured by CCD camera, the two-dimensional luminance ratio distributions of three primary colors can be computed. And the chromaticity coordinates of red, green and blue[3] of nine zones can be measured by the colorimeter. Thus, one can get the chromaticity coordinates of combination gray[4].

$$W = R + G + B \tag{1}$$

In the formula (1), the combination gray is composed of red, green and blue. However, in the experiment, the three primary colors are not equal to those in the formula (1) because of the low-contrast ratio of LCD projector.

$$\begin{aligned} R_{\text{test}} &= R + G_b + B_b \\ G_{\text{test}} &= R_b + G + B_b \\ B_{\text{test}} &= R_b + G_b + B \\ black &= R_b + G_b + B_b \end{aligned} \tag{2}$$

In the formula (2), R_{test}, G_{test} and B_{test} are the stimulus values of three primary colors, and R_b, G_b and B_b are the stimulus values of black background of three channels. In order to achieve the correct result, the black should be removed[5] from the combination gray, as shown in the formula (3).

$$\begin{aligned} W &= R_{test} + G_{\text{test}} + B_{\text{test}} - 2(R_b + G_b + B_b) \\ &= R_{test} + G_{\text{test}} + B_{\text{test}} - 2black \end{aligned} \tag{3}$$

Gray Level	Delta x	Delta y	Vector Delta xy
(50,50,50)	0.0008	0.0024	0.0026
(150,150,150)	0.0000	0.0006	0.0006
(250,250,250)	0.0010	0.0011	0.0015

Table 1: The difference of the chromaticity coordinates of the central zone of the screen taken by the colorimeter and the CCD-based color uniformity measurement system

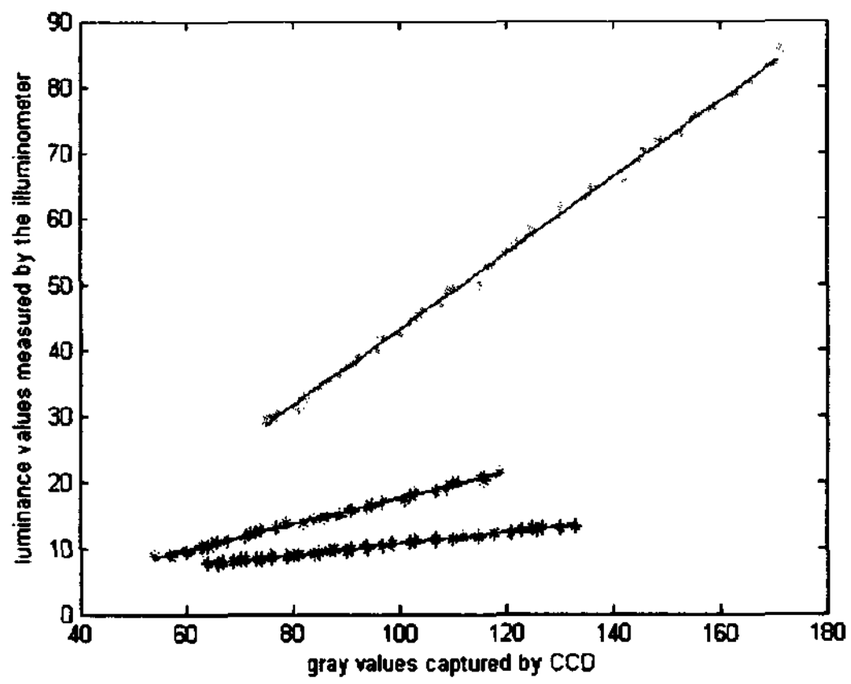

Figure 3: Luminance-gray curves of the central zone at gray level of 50

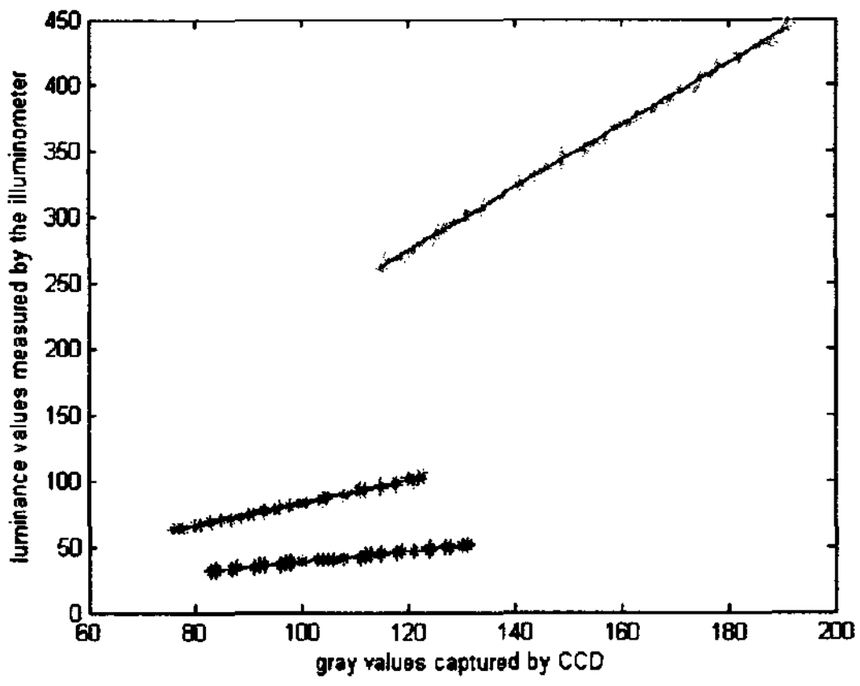

Figure 4: Luminance-gray curves of the central zone at gray level of 150

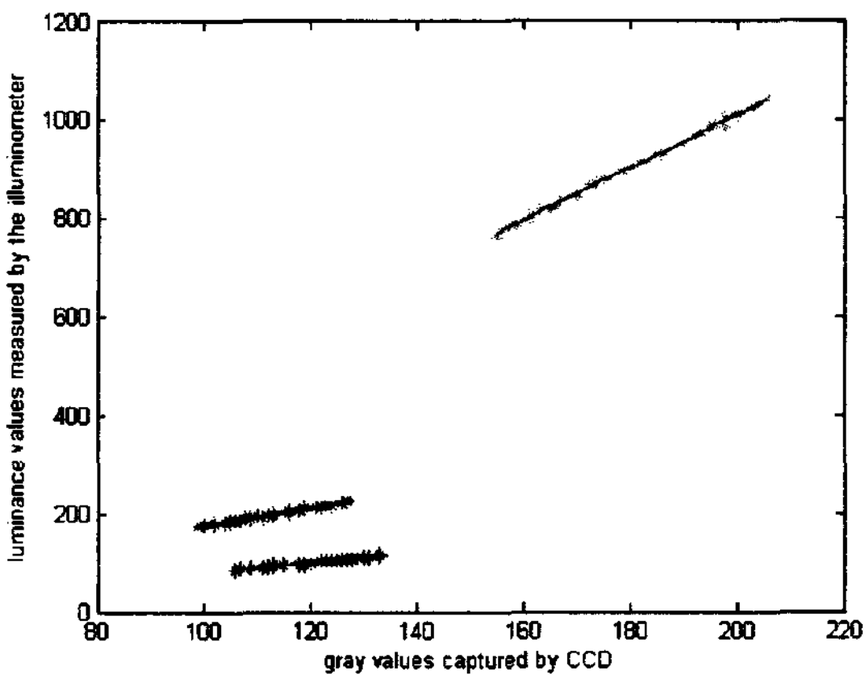

Figure 5: Luminance-gray curves of the central zone at gray level of 250

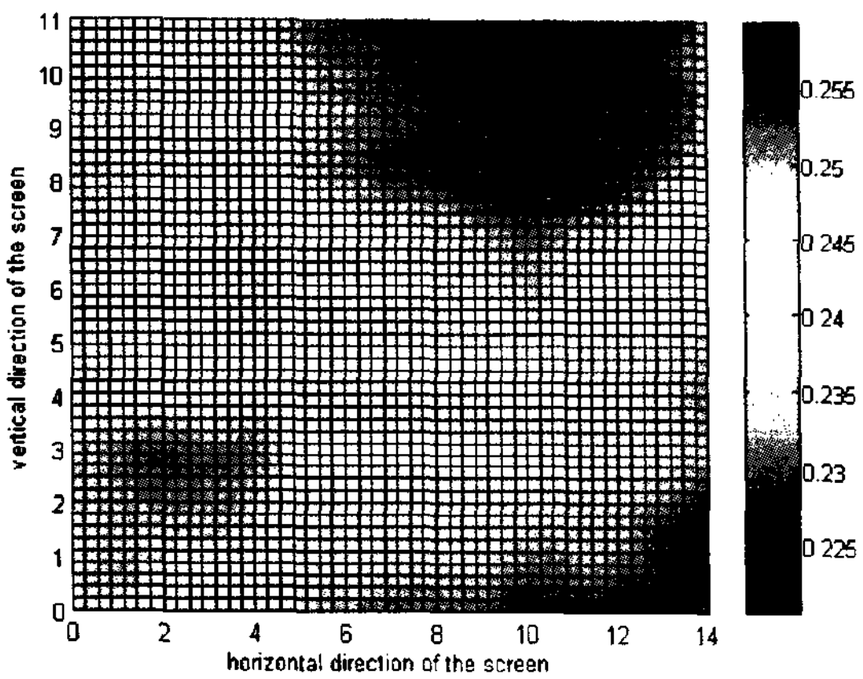

Figure 6: X chromaticity coordinate distribution of gray level of (50, 50, 50)

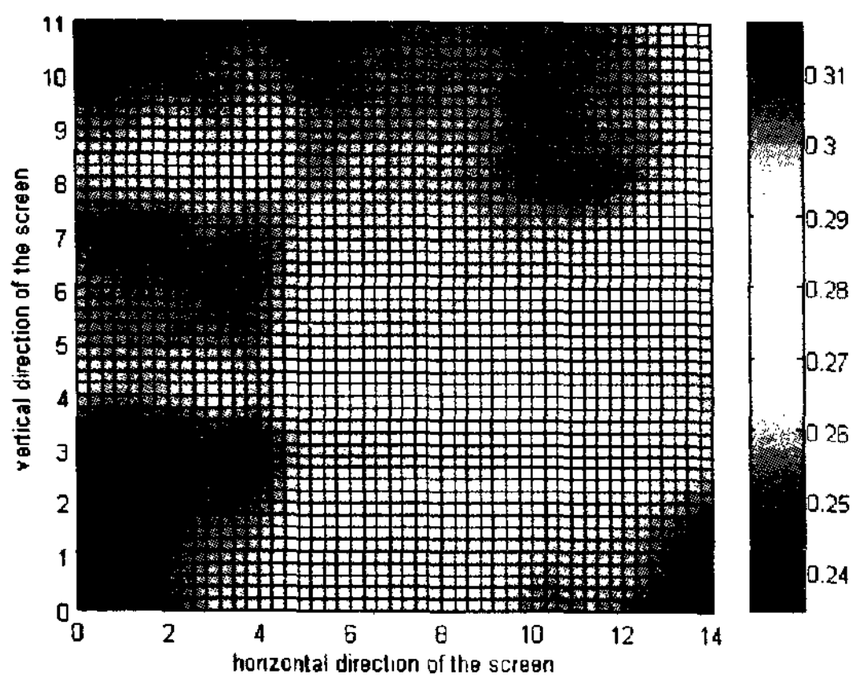

Figure 7: Y chromaticity coordinate distribution of gray level of (50, 50,50)

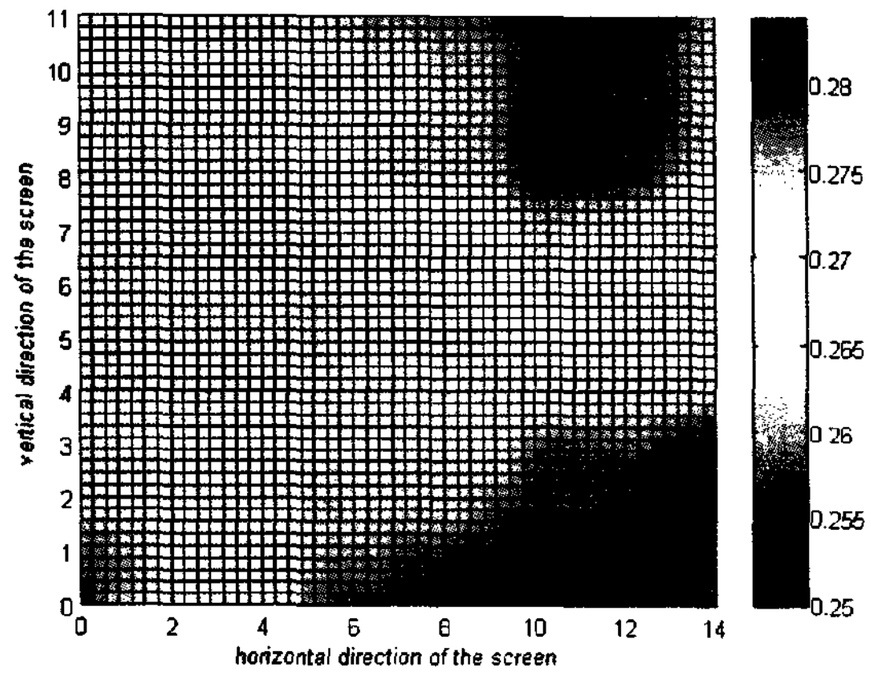

Figure 8: X chromaticity coordinate distribution of gray level of (150,150,150)

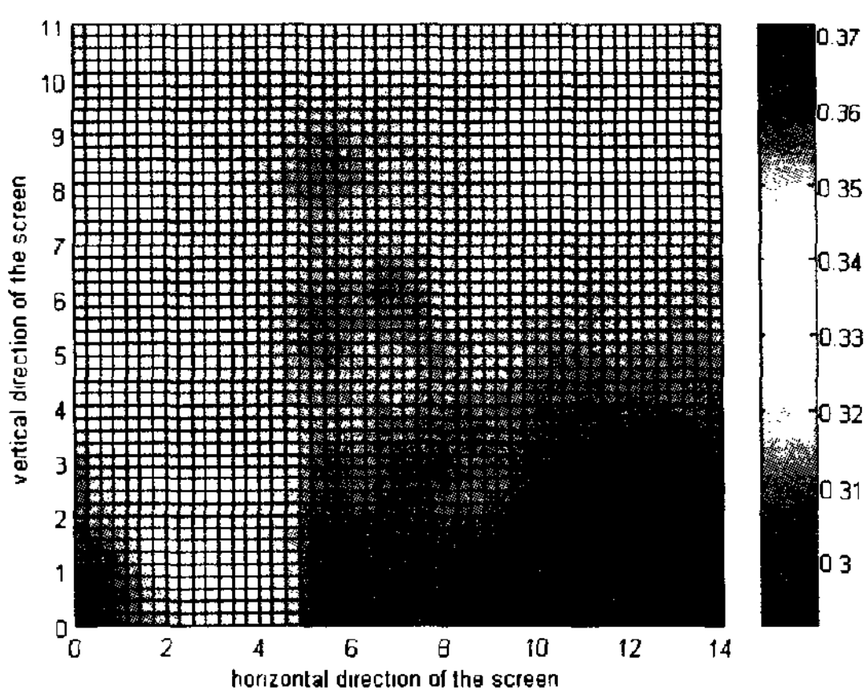

Figure 9: Y chromaticity coordinate distribution of gray level of (150,150,150)

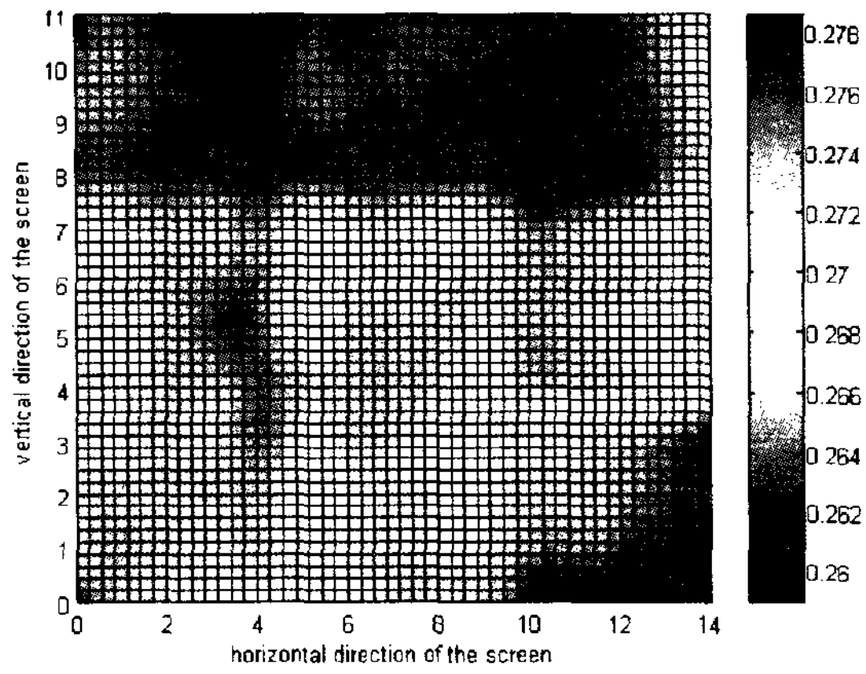

Figure 10: X chromaticity coordinate distribution of gray level of (250,250,250)

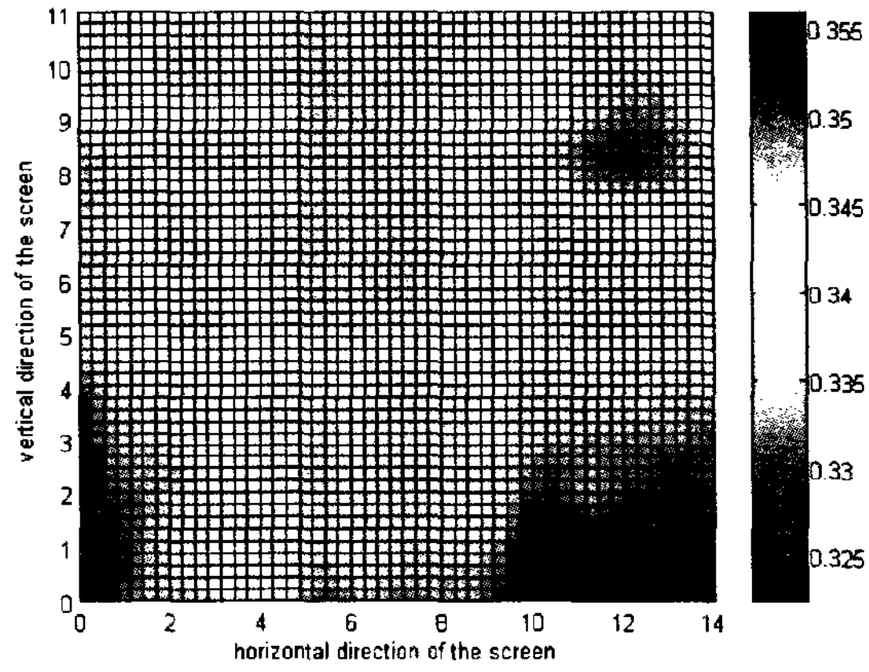

Figure 11: Y chromaticity coordinate distribution of gray level of (250,250,250)

3. Results and discussion

The difference of the chromaticity coordinates of the central zone of the screen taken by the colorimeter and the CCD-based color uniformity measurement system are shown in the table 1.

The screen was divided into 15 x 12 areas, the x and y chromaticity coordinate distributions of three levels of these areas were measured by CCD color uniformity measurement system. The results are shown in figure 6~11.

Comparing with the previous colorimeter and color CCD[2], the cost of monochrome CCD is lower. In addition, the method of calibration can accurately measure color uniformity of different gray levels, especially the lower gray level with bad color uniformity. It is better than the CCD photometer[2], which can only measure the chromaticity coordinates of the full white.

4. Conclusion

With the CCD measurement system, the test of the color uniformity of the LCD projector is rapid and convenient. From the analysis of the results above, one can find that the color uniformity distributions of different gray levels of the LCD projector can be achieved precisely. Thus, one can acquire the proper evaluation of the color uniformity of the LCD projector.

5. References

[1] ZWINKELS J., *Displays* 16, 163-171(1996).
[2] David R. Jenkins, Dingeman C, Beuzekom, *SPIE Proceedings*, Vol. 4295, 176-187 (2001).
[3] KWAK Y., MACDONALD L., *Displays* 21, 179-194 (2000).
[4] MACDONALD L., *Displays* 16, 203-211 (1996).
[5] Albert Cazes, Fred Mintzer, *SPIE Proceedings*, Vol. 4295, 267-278 (2001).