Spatial and Temporal Characteristics of LG StudioWorks 500LC (Flat Panel LCD)

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Abstract

Spatial independence and temporal stability of flat-panel LCD monitor, LG StudioWorks 500LC, were evaluated. The luminance and chromaticity of stimulus color were measured according to the variation of the size, background color, and location on the screen. The spatial independence at center location is very good and not a limiting factor in its colorimetric characterization, however the spatial non-uniformity is a little severe. The warmup time to stabilize after initial power is about 100 minutes and short-term variance of white stimulus is within 0.1 ΔE^*_{ab}.

1. Introduction

Flat-panel LCD monitors are quickly becoming a common peripheral for desktop PC. LCD displays are well known with greater luminance, better uniformity of space, time and color as well as thin and lightweight. The objective of this study is to examine a typical desktop LCD monitor's performance with respect to the spatial and temporal characteristics.

The colorimetric characterization of CRT displays has been achieved by an analytical model(1), which is based on a set of assumptions: temporal stability, spatial independence, channel independence, and chromaticity constancy. Display accuracy is limited by a lack of these assumptions(2). In this study, the approach is to evaluate the spatial independence and temporal stability for LCD display and determine if the traditional CRT techniques are also applicable to LCD display. The monitor evaluated is a commercial product available from LG, the StudioWorks 500LC.

2. Setup and Measurements

The test monitor was set to D65 white point, maximum brightness and contrast setting, 1024x768 at 75Hz, and 24-bit full color resolution. They were driven using the built-in video card (I740) of PC. Non-contact measurements were performed using a spectroradiometer CS-1000 of Minolta. The instrument optical axis should be the normal angle to the surface of the LCD. CS-1000 was focused with a measuring area of 1.6cm in diameter.

For testing the spatial independence, the size of displayed area was varied and the remainder of the display was set to various luminance and colors. In addition, the non-uniformity of luminance and chromaticity coordinates is measured at 13 locations over the entire LCD screen. Also the warmup time and stability were measured for white, gray, and black. With the exception of the warmup evaluations, all measurements were made after 2 hours of warmup and performed in a dark room. Moreover, image stabilization time was set 2 minutes after a displayed color change.

3. Spatial independence

Spatial independence is an assumption that the luminance and chromaticity at one pixel is stable and not dependent on the setting of other pixels in the display. As the size of displayed area is larger, the interreflection between pixel locations would be increased. This leads to the problem in additivity of the display. The additivity could be evaluated by comparing the sum of the measured luminances for RGB displayed individually with the measured luminance for the white. Table 1 shows the increase of difference as the diameter of central displayed area is increased with uniform black background. For highest accuracy, smaller image area is better than the full screen image. However, the additivity of this LCD display is quite good within 0.5%. In this study, all measurements were performed for an image of h/15 diameter just larger than measuring area.

Table 1. The difference between white and the sum of individual RGB primary measurements.

Spot	*W*	*R*	*G*	*B*	R+G+B	Diff.(%)
$h/15$	185.8	46.97	113.6	25.02	185.59	0.11
$5h/15$	187.2	47.30	114.5	25.15	186.95	0.13
$9h/15$	188.0	47.51	114.9	25.10	187.51	0.26
$13h/15$	188.5	47.66	115.3	25.03	187.99	0.27
$15h/15$	189.0	47.80	115.6	25.01	188.41	0.31
Full	189.6	47.93	115.9	24.87	188.70	0.47

Next, the spatial dependence on the 9 colors of background was evaluated. The tristimulus of white displayed on the center of the screen were measured varying to background color. These included black (0,0,0), gray

Table 2. ΔE^*_{ab} and MCDM for spatial independence measurements.

Back Color	X	Y	Z	ΔL^*	[illegible]	[illegible]	MCDM
0	177.8	186.4	176.4	0	0	0	
127	178.2	186.8	176.6	0.08	0.07	0.11	
255	180.3	188.9	178.3	0.52	0.20	0.56	
127r	178.0	186.6	176.6	0.04	0.01	0.04	
255r	179.1	187.1	176.7	0.15	0.61	0.62	0.24
127g	177.9	186.6	176.5	0.04	0.09	0.10	
255g	178.5	187.7	176.7	0.27	0.61	0.67	
127b	177.7	186.3	176.1	-0.02	0.08	0.08	
255b	177.8	186.2	177.1	-0.04	0.38	0.38	

(127,127,127), white (255,255,255), two reds {(255,0,0), (127,0,0)}, two greens {(0,255,0), (0,127,0)}, and two blues {(0,0,255), (0,0,127)}. The color difference induced by background color is listed in Table 2. We can see that spatial independence is affected by the luminance and chromaticity of the background. However these color differences were minimal with the MCDM(mean color difference from the mean) of 0.24. This indicates that there is very little spatial dependency for this LCD display. The spatial independence of the display is very good and not a limiting factor in its colorimetric characterization.

For the entire screen, the spatial uniformity was evaluated. White stimulus was displayed at one location and the remainder was displayed with black (0,0,0). The color differences for each location with respect to the center are shown in Fig. 1(a). The average ΔE^*_{ab} is 3.89 with maximum ΔE^*_{ab} of 6.59. The variation of luminance and chromaticity according to location is shown in Fig. 1(b). This large difference is due to the non-uniformity of backlight, RGB filter's coating material, density of liquid crystal, and so on. This display exhibit a lack of uniformity as usual displays.

4. Temporal stability

Short-term stability of color reproduction upon first applying power to the LCD is measured. The LCD should be powered down for more than 2 hours before the measurement. Fig. 2(a) shows the normalized luminance for white every minute for duration of 4 hours. Same test was performed for gray and black. The luminance increases quickly early on and then reaches a very stable level after about 100 minutes for all neutrals. Fig. 2(b) shows the short-time variance of these neutrals following 100-min. warmup and then measured 120 times. On average, short-time display uncertainty is within $0.1\,\Delta E^*_{ab}$. This variance might not cause uncertainty in colorimetric characterization.

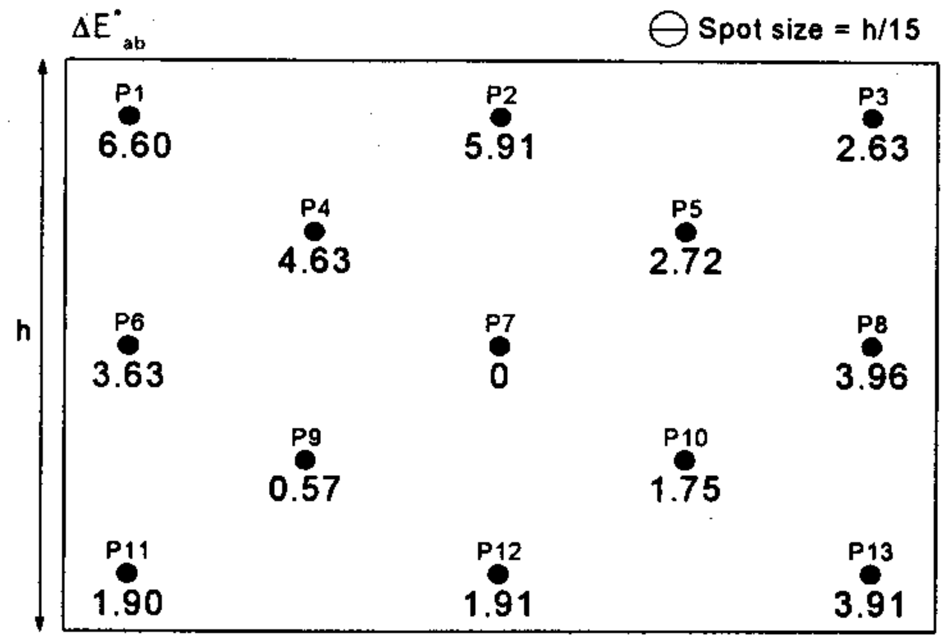
5. Conclusion

Spatial independence and temporal stability of LG Studio-Works 500LC were evaluated. The spatial independence is evaluated in terms of additivity, independence on background color, and non-uniformity. The spatial independence at one location is very good and the temporal stability is excellent after 100-min. warmup time. However, the accuracy of this display would be limited by spatial non-uniformity when entire image would be displayed.

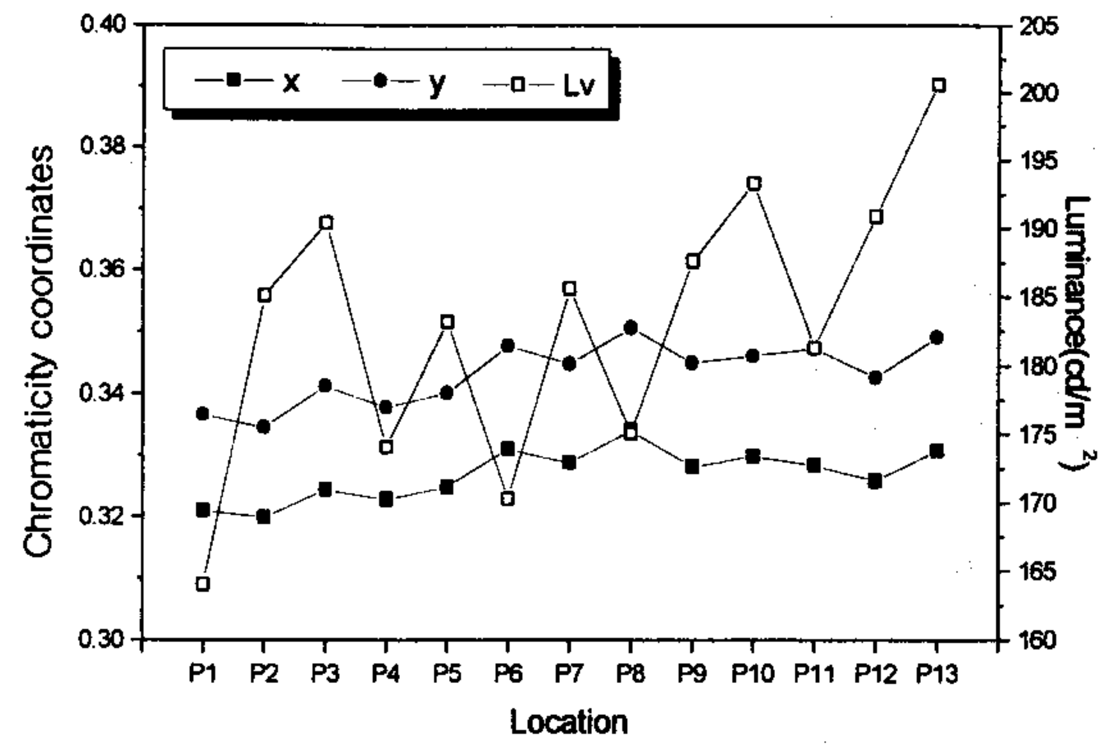
6. Reference

(1) Roy S. Berns, Ricardo J. Motta, and Mark E. Gorzynski, CRT colorimetry part I : Theory and practice, Color Res. Appl. **18**, 299-314(1993)

(2) Roy S. Berns, Ricardo J. Motta, and Mark E. Gorzynski, CRT Colorimetry. Part II: Metrology, Color Res. Appl. **18**, 315-325(1993)

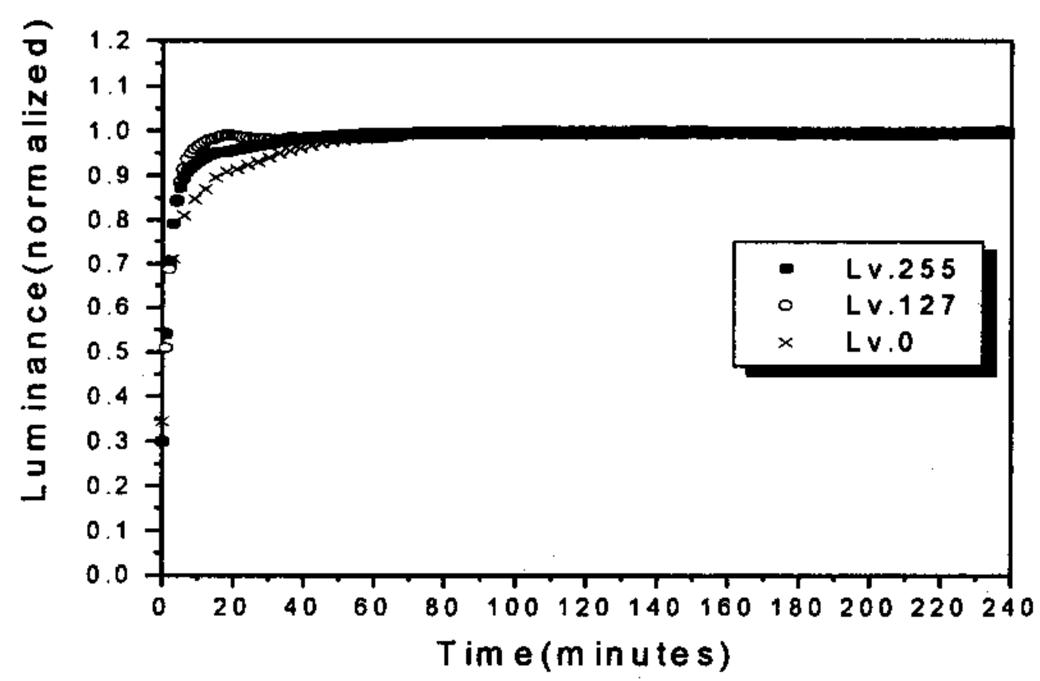


(a) CIELAB color differences

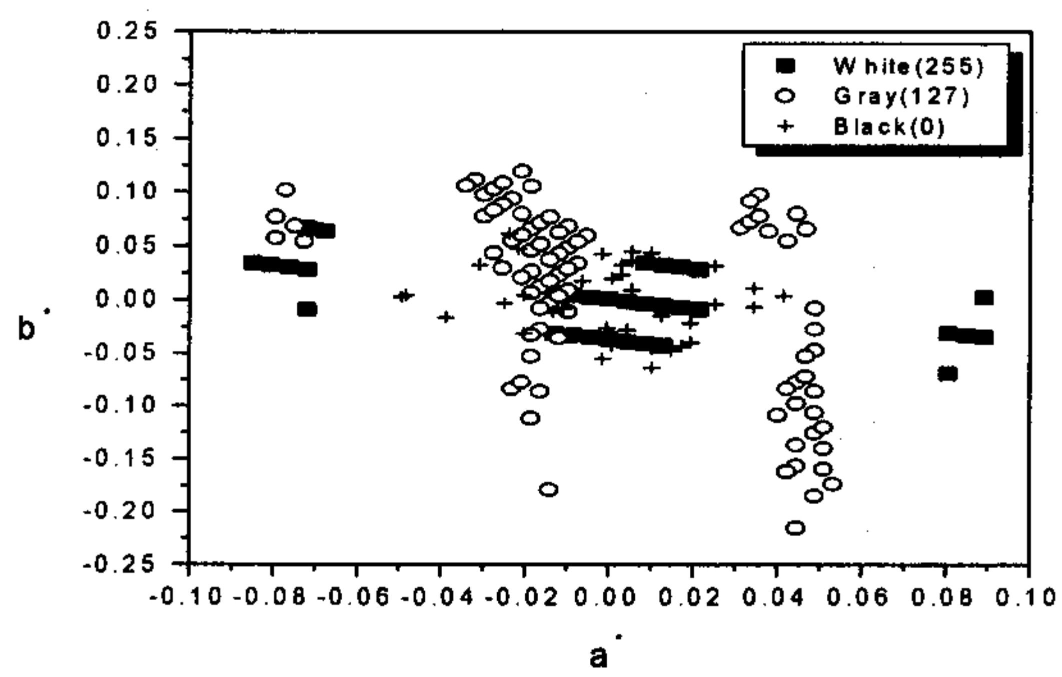


Luminance and chromaticity coordinates vs. location.

Fig 1. Spatial non-uniformity



(a) Normalized luminance measured over 4hours for monitor white, gray and black.



(b) Variation following 100 min. warmup.

Fig 2. Temporal stability