Display characterization for moving images

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Abstract

Color characterization of a display device commonly requires the measurement of CIE XYZ values of known samples displayed as patches on the device so that the relationship between the device space (usually RGB) and the device-independent space (XYZ) can be determined. However, it is known that the color measurements of the patches may vary with the color and luminance of the background against which they are displayed. Lack of spatial independence is one of the factors that can cause this phenomenon. This raises the question of what the nature of the background should be for an optimal characterization of a display system. It is likely that what is optimal will depend upon the intended application of the characterized display (for example, is it being used to display simple images in a psychophysical experiment or more complex images in some other setting). This research considers characterization with two background conditions (Mondrian-like colored background and Mondrian-like colored background with motion) and explores the effect of these background effects on the characterization model's parameters and on the usefulness of the characterization in various practical scenarios.

Introduction

Modern display technology (LCD and LED) has become increasingly popular because devices based on this technology are small, light and have low power consumption. Colorimetric characterization of a color display device is important for accurate color rendering of scenes. To control such displays precisely, it is essential to understand the relationship between digital input values and output colors. The GOG model [1] has been a popular choice for monitor characterization, particularly using the older CRT display technology. Some authors have advised against using the GOG model for characterization of LCD/LED displays in part because the nonlinearity of the displays may be not well suited to a gamma function but also because of lack of channel independence [2-3]. However, many modern displays effectively exhibit a gamma-like response because of manufacturers' desire for them to behave more like a CRT display (and hence facilitate market uptake of the new technology). The work in this paper is part of a wider project to explore characterization methods for modern display technology and to assess the effectiveness of the GOG model despite theoretical concerns about its applicability. In this paper, the effect of the background color on the color measurements of calibration patches is explored. The effect of having grey, white or black backgrounds are well known in the literature [2] and variations in color as a result of background are described as lack of spatial independence. In our study we are interested in whether motion in the background field could affect the color of a central calibration patch. In many situations device characterization is carried out and subsequently used for moving images. Therefore, one of the background conditions that we have explored is that where the background is not static. Some preliminary results based on one display device and a small number of color stimuli were previously published [4].

Experimental

A PhotoResearch CS1000 spectroradiometer was used to make measurements of stimuli displayed on three modern displays: (1) HP DreamColour LP2480zx; (2) EIZO ColorEdge CG220; (3) NEC Multisync 1960Nxi. Measurements were made in a darkened room using the spectroradiometer mounted on a tripod so that the measuring distance was fixed at 1 m. Stimuli were generated on the display using a MATLAB GUI so that specific colors (generated with known RGB values) in different backgrounds could be displayed. The color patches were 6 cm × 6 cm displayed on a background that otherwise filled the display screen. Measurements were made using the spectroradiometer from the centre of each color stimulus.

Table 1- Samples used in the experiment.

No.	R	G	B
1	50	50	50
2	255	255	255
3	128	128	128
4	200	200	200
5	255	0	0
6	0	255	0
7	0	0	255
8	0	255	255
9	255	0	255
10	255	255	0
11	128	180	50
12	235	225	150
13	50	128	180
14	180	128	50
15	50	180	128
16	125	0	10
17	245	85	10
18	205	165	255
19	115	45	0
20	0	0	0

The spectroradiometer setting was such that the instrument automatically integrated light from the display until a sufficiently accurate reading was taken.

Twenty colors were measured (see Table 1 for the RGB specifications) and these were chosen to include black, white, different grays, the additive primary colors (red, green and blue), secondary colors (cyan, magenta and yellow) and a few colors where all three primaries were moderately active. Measurements were taken for each color displayed against two backgrounds: (a) Mondrian and (b) Mondrian with movement.

The spectroradiometer measured CIE XYZ values (1964 standard observer), which were downloaded to a computer and subsequently analyzed. The Mondrian background was selected so that the effect of motion in the background can be explored by directly comparing conditions (a) and (b).

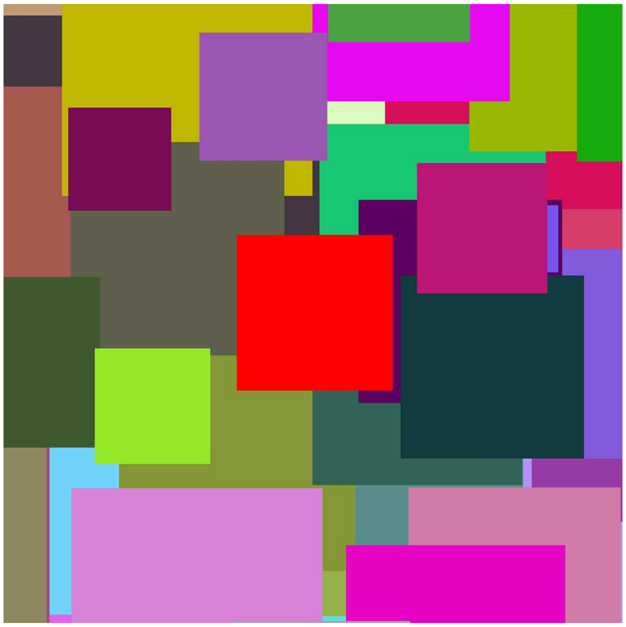


Figure 1: Color stimulus displayed against Mondrian and Movie backgrounds. In one condition (Mondrian) the background is static whereas in the other condition (Movie) the Mondrian-like background pattern drifts diagonally across the screen. In both conditions the central patch (stimulus) remains stationary.

Figure 1 shows an illustration of a typical color stimulus displayed against Mondrian-like background. In one condition (Mondrian) the background is static whereas in the other condition (Movie) the Mondrian-like background pattern drifts diagonally across the screen at a rate of about 0.01 m/s. In both conditions the central patch (stimulus) remains stationary. The Mondrian was generated using a specially developed algorithm so that each patch of the Mondrian pattern had a random color and size (within certain constraints). The central patches were measured and the measurements were compared using the CIELAB and CIEDE2000 color-difference equations. Measurements were made 3 times for each of the three displays and each of the two conditions. The order of measurement was totally randomized each time. The XYZ values were averaged for each display and monitor and were then multiplied by $100/Y_W$ where Y_W was the Y value of the white sample so that Y =100 for the white in each case.

Results

Tables 2 and 3 show the average relative XYZ values of the color patches for each of the three displays for the Mondrian and Movie conditions respectively.

Table 2- XYZ values for Mondrian condition.

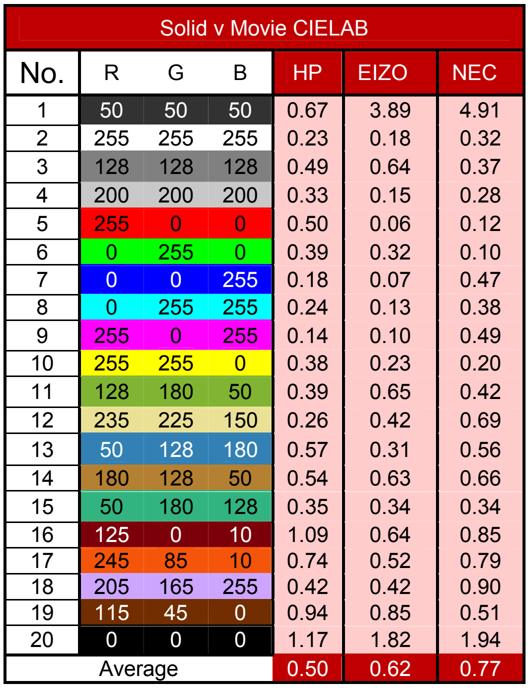
	Average relative XYZ								
	HP			EIZO			NEC		
	X	Y	Z	X	Y	Z	X	Y	Z
1	2.91	2.95	3.29	3.67	3.74	3.84	2.62	2.71	3.09
2	98.51	100.00	107.04	98.02	100.00	110.83	96.38	100.00	107.86
3	22.80	23.64	24.91	23.33	23.68	25.77	23.47	24.70	26.72
4	61.17	63.14	67.78	59.07	59.66	66.68	59.71	62.17	68.44
5	59.39	26.34	1.20	61.42	31.78	2.15	47.31	25.32	1.20
6	21.20	69.32	7.34	19.25	62.28	6.77	31.69	66.06	10.39
7	19.08	5.44	99.99	19.53	9.04	104.38	18.15	9.32	97.48
8	39.74	74.19	106.59	37.70	69.72	109.59	49.43	75.06	107.34
9	77.81	31.24	100.47	79.95	39.99	105.67	65.12	34.28	98.19
10	80.09	95.13	7.95	79.93	92.73	8.15	78.76	91.21	10.92
11	24.61	41.09	6.79	24.18	36.55	7.09	27.52	39.43	7.92
12	73.47	79.86	39.46	71.77	75.08	40.27	71.08	76.69	41.24
13	16.02	19.75	51.22	15.69	19.39	50.11	18.23	21.77	52.09
14	34.12	29.18	5.15	34.12	29.33	5.94	31.37	29.07	5.54
15	16.57	36.94	26.53	15.61	31.98	26.76	21.47	36.10	29.17
16	12.74	5.81	0.78	13.26	7.08	1.10	10.75	5.88	0.80
17	56.53	30.47	1.82	58.10	34.76	2.62	46.84	29.55	2.05
18	63.53	50.08	103.14	63.12	51.64	107.07	59.94	51.93	102.54
19	11.11	6.27	0.84	11.85	7.61	1.12	9.52	6.17	0.98
20	0.42	0.39	0.60	0.63	0.62	0.76	0.45	0.42	0.67

Table 3- XYZ values for the Movie condition.

	Average relative XYZ								
	HP			EIZO			NEC		
	X	Y	Z	X	Y	Z	X	Y	Z
1	3.00	3.03	3.29	4.82	4.86	5.28	3.88	3.91	4.25
2	98.64	100.00	107.09	98.12	100.00	110.93	96.42	100.00	108.36
3	22.51	23.27	24.53	23.12	23.40	25.74	23.15	24.36	26.46
4	60.99	62.83	67.41	58.90	59.53	66.54	59.98	62.46	69.03
5	59.26	26.31	1.23	61.50	31.82	2.16	47.16	25.22	1.19
6	21.17	69.16	7.38	19.28	62.26	6.84	31.64	66.01	10.37
7	19.10	5.43	99.95	19.55	9.05	104.36	18.24	9.33	97.97
8	39.70	74.02	106.35	37.75	69.74	109.56	49.48	75.01	107.80
9	77.65	31.19	100.36	79.94	39.99	105.55	65.02	34.17	98.67
10	79.74	94.79	7.97	79.91	92.60	8.17	78.49	90.98	10.91
11	24.26	40.65	6.69	23.91	36.33	6.91	27.16	39.00	7.84
12	73.09	79.43	39.05	71.64	74.95	39.83	70.99	76.37	41.44
13	15.80	19.41	50.76	15.61	19.24	49.93	18.02	21.46	51.78
14	33.78	28.78	4.99	33.98	29.13	5.75	30.92	28.62	5.51
15	16.36	36.54	26.16	15.53	31.86	26.45	21.24	35.72	28.89
16	12.61	5.79	0.83	13.10	7.03	1.11	10.56	5.80	0.82
17	56.11	30.17	1.84	57.92	34.64	2.67	46.37	29.10	2.04
18	63.05	49.61	102.76	63.11	51.51	107.30	59.84	51.58	102.86
19	10.93	6.18	0.87	11.59	7.47	1.12	9.27	5.97	0.94
20	0.48	0.46	0.61	0.76	0.74	0.97	0.61	0.60	0.78

Table 4 shows the CIELAB colour differences between the Mondrian and Movie conditions for each of the three monitors. The average color differences are 0.50, 0.62 and 0.77 for the HP, EIZO and NEC displays respectively.

Table 4- CIELAB color differences between the two conditions.



Solid v Movie CIELAB						
No.	R	G	B	HP	EIZO	NEC
1	50	50	50	0.67	3.89	4.91
2	255	255	255	0.23	0.18	0.32
3	128	128	128	0.49	0.64	0.37
4	200	200	200	0.33	0.15	0.28
5	255	0	0	0.50	0.06	0.12
6	0	255	0	0.39	0.32	0.10
7	0	0	255	0.18	0.07	0.47
8	0	255	255	0.24	0.13	0.38
9	255	0	255	0.14	0.10	0.49
10	255	255	0	0.38	0.23	0.20
11	128	180	50	0.39	0.65	0.42
12	235	225	150	0.26	0.42	0.69
13	50	128	180	0.57	0.31	0.56
14	180	128	50	0.54	0.63	0.66
15	50	180	128	0.35	0.34	0.34
16	125	0	10	1.09	0.64	0.85
17	245	85	10	0.74	0.52	0.79
18	205	165	255	0.42	0.42	0.90
19	115	45	0	0.94	0.85	0.51
20	0	0	0	1.17	1.82	1.94
Average				0.50	0.62	0.77

Figure 2 shows a plot of the difference between the Mondrian and Movie condition against the Y value of the Mondrian condition for the HP display. The differences are almost all positive which indicates that the Y values of the Mondrian display were consistently greater than the corresponding Y values of the Movie display.

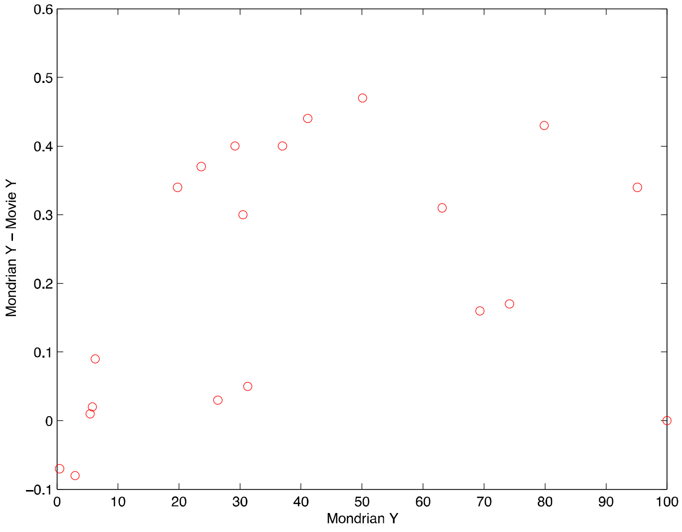


Figure 2: Difference between Mondrian and Movie Y value plotted against Mondrian Y value for each color stimulus (HP display).

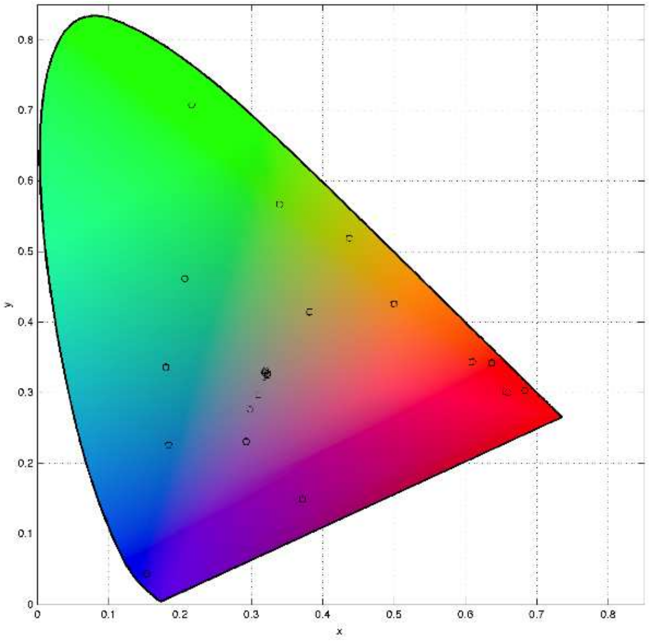


Figure 3: CIE chromaticity coordinates for Mondrian (circle symbols) and Movie (square symbols) conditions respectively (HP display).

Figure 3 indicates the CIE chromaticities of the Mondrian and Movie conditions for the HP display. With the exception of the black sample there are very few differences between the two conditions. Figures 2 and 3 would seem to indicate that the effect of the moving background is to reduce the Y value of the color stimuli with little of no effect on chromaticity. But is this effect significant and is it replicated in the other two displays that were studied?

A one-sample t-test was carried out to test the hypothesis that the color difference (0.50) between the two conditions was distinguishable from zero. The result was that the difference was statistically significant ($p < 0.01$).

The data were also analyzed for the other two displays. In both cases, no effect on chromaticity was observed for the background condition. However, Figures 4 and 5 show that the Y values for Mondrian condition were, for both displays, greater than the Y values for the Movie condition. Thus, for all three displays there seems to be an effect that the Movie condition causes a small reduction in luminance. The color differences for the EIZO and HP displays were 0.62 ($p < 0.01$) and 0.77 ($p < 0.01$) respectively and both were significantly greater than zero.

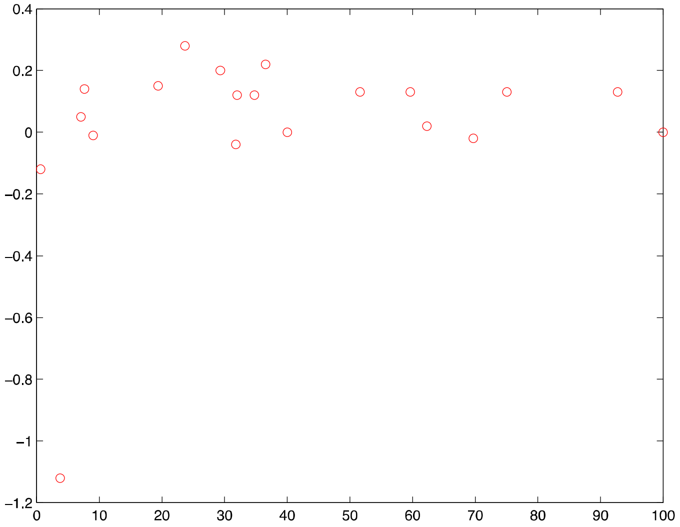


Figure 3: Difference between Mondrian and Movie Y value plotted against Mondrian Y value for each color stimulus (EIZO display).

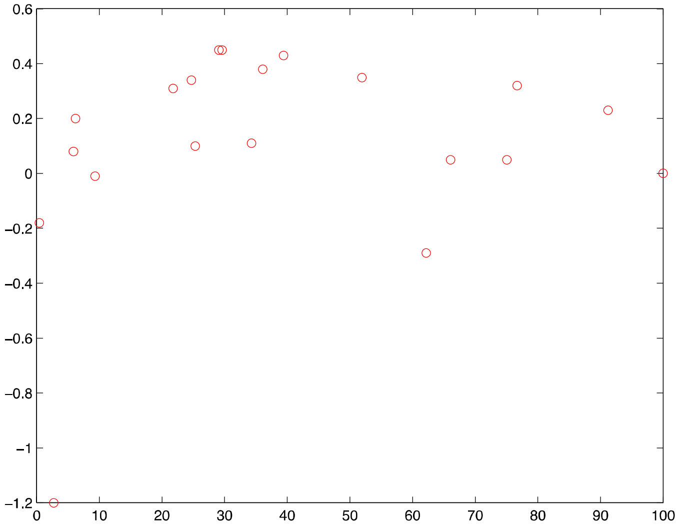


Figure 4: Difference between Mondrian and Movie Y value plotted against Mondrian Y value for each color stimulus (NEC display).

Conclusions

A novel stimulus has been used to show that the color of a calibration patch depends not just on the color and lightness of the surround but also on whether the surround is moving. This has implications for the design of stimuli for use when building display characterization models and suggests that if these models are to be used to process movies then measurements should be taken on a moving background.

1. Berns, R.S., Motta, R.J, & Gorzynski, M.E. 1993. CRT colorimetry part 2. Metrology. Color Research & Application, 18, 315-325.
2. Berns, R.S and Katoh, N. (2002) Methods for characterising displays, in Colour Engineering, P. Green, and LW, Macdonald (eds.) John Wiely & Sons, Ltd, Chichester.
3. Day, E.A., Taplin, L. & Berns, R.S. 2004. Colorimetric characterization of a computer-controlled liquid crystal display. Color Research & Application, 29, 365-373
4. Vazirian, M., Westland, S, & Cheung, V 2013. Effect of background colour on monitor characterization, Proceedings of the AIC Congress, 391-394.