A Study on the Evaluation Method of Perceptual Contrast with CIECAM02

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Abstract

The contrast of display is one of the important specifications. Even if the contrast indicates luminance range which is a capability of the display and is greater in lower luminance or higher luminance, we consider that the greater contrast gets not the better performance. It is not the same value in human visual system. In practice, it is difficult to achieve the full dynamic range seen by human beings using electronic equipment. Therefore, we consider ambient condition and human perception to calculate perceptual contrast using the CIECAM02. In this paper, we propose perceptual contrast that is calculated using the brightness of CIECAM02.

1. Introduction

A current evaluation method for the image quality of display device is good enough to measure the efficiency of the display devices. The image quality of a display is numerically expressed using the contrast ratio, luminance, and color gamut (the area of polygon observed from CIE 1931 *xy* or 1976 *u'v'* chromaticity diagrams). However, these quantified numbers are not effectively correlated with human's perceptual opinions. Furthermore, external illumination condition, which is not considered in the indices mentioned previously, significantly biases human's perception. Therefore, the novel standard method for the reflection of human sensing mechanism, such as lighting and chromatic adaptation action of eyes, is required. Color appearance models provide equations and methods to calculate the color appearance in different viewing conditions. The color appearance of a display varies with the viewing conditions, such as different illuminants, luminance level, background, surrounding colors. Color appearance models provide equations and methodologies to evaluate the color appearance in different viewing conditions and have been successfully applied in color industries. Several color appearance models, such as Hunt94[2], Nayatani, and CIECAM97s, have been proposed to predict some of the effects, based on color vision theories and available experimental data. In 2002, a CIECAM02, another color appearance model, was proposed in CIE TC8-01. Then, this model was recommended by the CIE. Compared with CIECAM97s[3], the CIECAM02[4] is simpler in formulation, easier to invert, and performs better for all available data sets. Most of the color appearance phenomena are evaluated by CIECAM02. The contrast carries out a part to offer the important information about a shape of objects in the image. So we believe that it is very important to evaluate the contrast considering human's perception for representing a correct quality of image. We have already measured the luminance of another device and evaluated the contrast of luminance and contrast of brightness by human feelings. In this paper, we propose that novel perceptual contrast determined by the brightness of CIECAM02 is more effective to evaluate human's perception than the contrast obtained using luminance levels.

2. Experimental

The investigation was divided into two parts, experiments comparing contrast at luminance levels with contrast in brightness and experiments comparing contrast of display in different illuminant conditions. All experiments were conducted in a darkened room. A 4 inch AMOLED display was used for the experiments. The ALOLED display was calibrated to set white point and warmed up more than 30 minutes to ensure the repeatability and stability

before any assessments were made. In a range of 0 lux and 15,000 lux of integrating sphere, the color coordinates of the black and white color were obtained using a Topcon BM-5A. A data set for investigating the perceptual contrast was obtained from a series of physical experiments. The data set was accumulated to test the color appearance model. The experimental set up is shown schematically in Fig. 1.

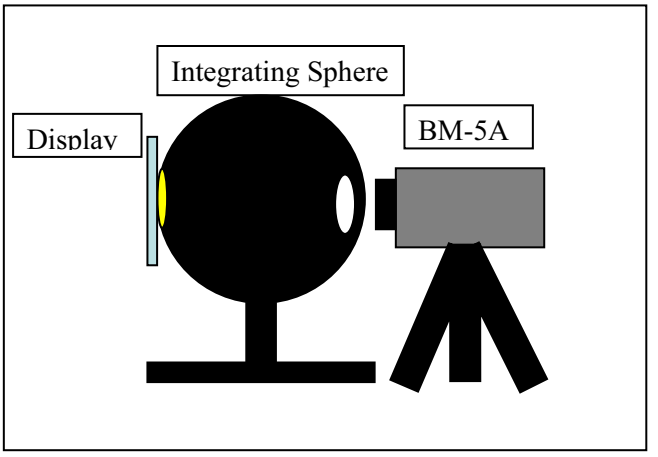

Fig. 1. The contrast measurement system.

3. Results and discussion

3.1 CIECAM02 Model

The CIECAM02 model was adapted to evaluate the perceptual contrast by the luminance data of the displays. The structure of the CIECAM02 is described in CIE TC8-01. In the CIECAM02 model, the tristimulus values of the stimulus are transformed into the spectrally sharpened cone responses, using a linear transformation matrix M_{CAT02}. The chroma adaptation (RcGcBc) is obtained using a Von-Kries function, which includes the degree of adaptation D and are correlated to the reference white. The post adaptation values are converted into a specific type of equal area cone fundamental denoted R'G'B'. Finally, a response compression (R'aG'aB'a) is applied to the cone fundamentals. The flow chart of CIECAM02 is shown in Fig 2.

The brightness (Q) is adjusted by the contrast factors c, z and the surround luminance compression factor F_L to represent compression effects caused by background contrast and surround luminance. Correlation of lightness (J) and brightness (Q) are computed as follows:

$$A = (2R'a + G'a + 0.05B'a - 0.305)N_{bb} \quad (1)$$

$$J = 100(A / Aw)^{cz} \quad (2)$$

$$Q = (4 / c)\sqrt{J / 100}(Aw + 4)F_L^{0.25} \quad (3)$$

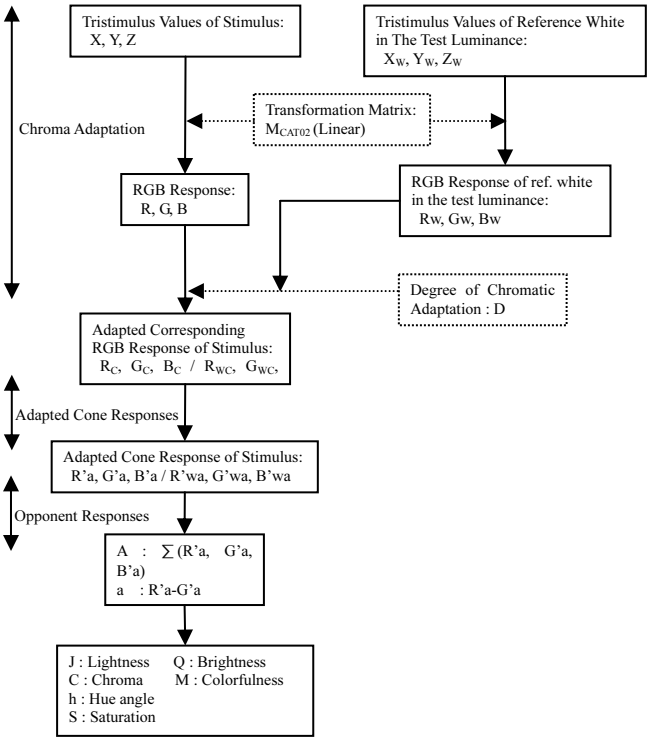

Fig. 2. Flow chart of the CIECAM02.

3.2 Perceptual Contrast under Viewing Condition

The contrast generally refers to the ratio of intensities between the most intense and the least intense element of a display, regardless of perceptual attribute. First, in a darkened room, the observed contrasts of AMOLED with AR(Anti-Reflection) polarizer and LCD are 41,840 and 207.28, respectively, as shown in Table 1. The big difference stems from low luminance level of AMOLED at black signal. The luminance of displays in living room is far brighter than in darkend room and the contrast is the smaller, as shown in Table 3. However, people cannot feel such drastic difference. It is thus believed that this value does not realistically represent the perception, which motivated us to consider the brightness of CIECAM02 to get the perceptual contrast according to the surround condition.

The perceptual contrasts of AMOLED and LCD are 9.45 and 3.41, respectively, as shown in Table 2. It is perceived in darkened room that the brightness at black signal of LCD is about 3 times larger than that of AMOLED because of the substantially reduced surround illumination and adaptation.

Though measured luminance of the display is lager in viewing condition, such as office, stores or under the shade at noon, it is different from perceptual brightness. So the surround illumination should be reflected in the contrast, as shown in Table 4. In 15,000 lux, the observed luminance of AMOLED and LCD at white signal is 238 cd/m^2 and 526 cd/m^2 and the calculated brightness of CIECAM02 is 204 and 251. The perceptual brightness in illumination is less than in darkened room as brightness of CIECAM02, inclusive of adaptation condition. Otherwise, the perceptual brightness in illumination is more than in darkened room according to black signal. So the contrast, namely, the range of brightness of display becomes narrow.

TABLE 1. The contrast measured using luminance level

	Luminance		
	Black	White	Contrast
AMOLED	0.005	209.2	41,840
LCD	1.25	259.1	207.28

TABLE 2. The perceptual contrast obtained using the brightness of CIECAM02

	Brightness of CIECAM02		
	Black	White	Perceptual Contrast
AMOLED	27.62	261.13	9.45
LCD	79.92	272.87	3.41

TABLE 3. The contrast measured using luminance level

Illumination	AMOLED		
	Black	White	Contrast
1000	1.819	209.7	115.28
5000	10.73	216.5	20.18
10000	22.85	227.8	9.96
15000	34.73	237.7	6.84

Illumination	LCD		
	Black	White	Contrast
1000	14.8	273.8	18.5
5000	82.75	341.3	4.12
10000	174.2	433.3	2.49
15000	267.2	526.2	1.977

TABLE 4. The perceptual contrast obtained using the brightness of CIECAM02

Illumination	AMOLED		
	Black	White	Perceptual Contrast
1000	53.73	198.94	3.70
5000	87.75	200.27	2.28
10000	107.78	202.39	1.88
15000	120.63	204.18	1.69

Illumination	LCD		
	Black	White	Perceptual Contrast
1000	94.37	210.17	2.23
5000	149.44	219.94	1.47
10000	180.36	231.06	1.28
15000	200.13	240.52	1.20

4. Summary

In this paper, we present that perceptual contrast is better evaluated by using the brightness of CIECAM02 than by comparing luminance. Due to extremely low luminance of the black color of AMOLED, the luminance contrast between black and white is 200 times larger than that of LCD, which clearly exceeds human's perceptions. When CIECAM02 is applied, perceptual contrast of AMOLED is about 3 times larger than that of LCD in darkened room and the range of brightness of display becomes narrow in ambient condition, which is realistic. So we suggest that the "perceptual contrast" using CIECAM02 should be used. The perceptual contrast clearly better represent human's perception than comparing luminance in viewing condition.

5. References

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