A Novel Method to Evaluate the Emotional Image Quality with CIECAM02

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Abstract

We propose a new method evaluating the image quality of display devices using the CIECAM02 that is the recently developed CIE color appearance model and provides an extension of the previously recommended CIE color spaces. We develop the evaluation method that quantifies the color reproduction capability, emotional gray scale (gradation), and visual perception contrast (perceptual contrast range) based on the gamut in this model.

1. Introduction

A current measurement method to evaluate an image quality of display device is useful only when performance of characteristics, such as luminance, contrast ratio, color gamut area (gamut of the three primary colors on the CIE 1931 *xy* or 1976 *u'v'* chromaticity diagram) and response time, is mainly considered. And the majority of display industries are interested in this performance.

In color part, the experiments conducted to achieve a color scale diagram were performed by evaluating the colorimetry of displays with calculation of correlated color temperature and color rendering indices. Though the specifications of displays are similar in chromaticity diagram, there are different perceived colors in different viewing fields and luminance level. It is not adequate to describe a discrepancy between the specification and the visual experience, as yet. So in recent years, many studies have been advanced to get a color appearance model accorded an optical perception. It should describe the perception of colors, in order to reflect human visual system (HVS) such as perceptual of lightness and chromatic adaption.

It should be noted that the CIECAM02 model has been announced by CIE (Commission Internationale de l'Eclairage) as a color appearance model for color imaging applications. It has been derived from the CIECAM97s model[3], but embodied in some simplifications and improvements that enhance its performance in a color management condition. In using the CIECAM02, we try to evaluate image quality of display using the perceptual correlates of lightness, chroma and hue or the perceptual attributes of brightness, colorfulness and hue and to get them each set of coordinates representing an appearance color space. The adoption of the CIECAM02 is influenced by the visual environment within which the viewing takes place. It is applied to calculate to perceived information of the displayed color. It has been based upon experimental data, involving numerous human subjects, and incorporating assessments of actual visual observations of color appearance made under a wide range of viewing conditions.

In this paper, we propose a novel method for evaluating the image quality of displays using the CIECAM02[1]. We develop the evaluation method that quantifies the color reproduction capability and perception contrast based on the gamut in this model. It is more effective CIECAM02 to evaluate brightness and colorful in 3-D polar coordinates[4] than general method evaluated by the 2-D Cartesian coordinates and luminance level each other.

2. Approaches

In order to evaluate the perceptual image quality of displays, tristimulus colorimeters of primary color

signal range from 0 to 255 at the TV and mobile display set in a darkened room are measured and transformed into perceptual attributes of CIECAM02 in a dim surround[2]. Displays get warmed up more than 30 minutes to make the stability. For mobile applications where surround condition is required, it is necessary to control a given illumination such as 0 lx, 500 lx and 1,000 lx for various actual colors to be measured. The perceptual attributes come in various evaluation factors based on modeling the HVS. Rarely in the case of evaluation, color reproduction capability is obtained from perceptual attributes of a scale of primary colors and perceptual contrast is calculated from brightness range of display. It is required surround conditions are used while calculating the output attributes.

2.1 CIECAM02

The CIECAM02 was announced in 2002 to model a part of color appearance. It uses sample tristimulus values as input parameters and has several additional input parameters that are white tristimulus value, surround condition, luminance of the adapting field and the luminance of the background. The color space has not only perceptual correlates for lightness, chroma and hue andgle but also the perceptual attributes of brightness, colorfulness. The steps for using CIECAM02 are explained in Fig 1.

The value obtained by converting several human visual features from experiment or study with conversion formula and substituting for XYZ tristimulus values indicates our perception similarly. The CIECAM02 in distraction from L*a*b* and L*u*v* considers viewing condition parameters such as luminance of the adapting field, background luminance and surround condition.

The biggest advantage of CIECAM02 from the aspect of output is that it fully copes with the roles of L*a*b* or L*u*v*. Like Munsell color system, it can obtain perceptual attributes and correlates.

If expressing color reproduction capability using existing L*a*b* or L*u*v*, the brightest white luminance value of device was normalized with maximum of L as 100 and the darkest black value as 0. In this case, it is possible to compare panels with same maximum and minimum luminance but hard to compare panels with different luminance. If expressing as brightness (Q), colorfulness (M), and hue angle (h) of CIECAM02, however, it is likely to totally compare between different panels since It require to apply brightness which means that human perceives the absolute lightness and there is no boundary of luminance value.

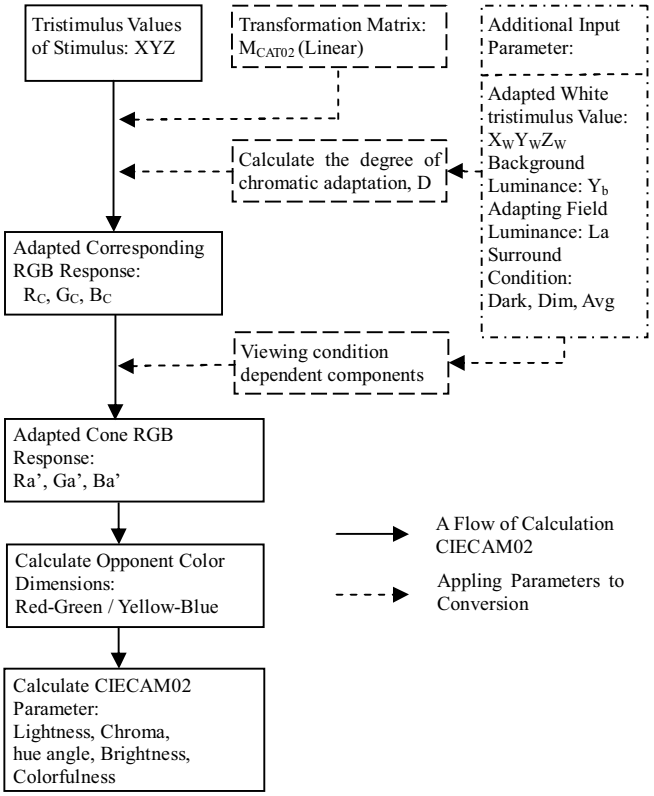


Fig. 1. The Steps for using CIECAM02.

2.2 Color reproduction capability

A method indicating a color reproduction capability of displays calculates the volume of color range in perceptual attributes, instead of the area of color gamut and luminance. Though the primary colors are very dim at low signal, it is similar in chromaticity diagram to the vivid primary colors at the maximum, as displays are measured for spectral radiance to obtain colors. However, it is generally not accord with an optical perception. It is because existing measuring method and CIE chromaticity diagram do not reflect human vision and color perception mechanism such as adaptation and the lighting conditions.

A color reproduction capability related to gamut volume is expected to compute the relative size of the gamut volumes in dim surround as a function of color expression. Tristimulus values measured from black to white, red, green and blue were then converted to CIECAM02 coordinates. The QMh values are converted to rectangular coordinates. The nearest points in 3-D coordinates are linked and the triangular pyramid set computed by algorithm of Delaunay triangulation is made of them. The volume of color

range is the sum of the pyramid volume.

2.3 Perceptual contrast

Industries have focused on measuring luminance of black and white signal as a means of assessing contrast ratio and developed a glaring display to enhance to value of contrast ratio and it makes a vivid image in sunny day. But doubts have been expressed about the contrast calculated by measuring data separately, since we rarely see colors in isolation. Stimuli of colors in display interact with each other and change our perception accordingly.

Theoretically a low black luminance is important as a point of reference but it is necessary to consider the stimulus for the noticeable difference. For example, there are two different displays the black luminance of which is 0.01 cd/m^2 and 0.02 cd/m^2 each other and the white luminance is the same. According to the numbers, the contrast, that white luminance is divided by black luminance equally, is twice as many the former as the other. But it is unable to perceptually discriminate two times. The noticeable difference has subjective recognition leads to a logarithmic rule relating the level of sensation to the stimuli. So we expend the concept of contrast ratio to perceptual contrast range that is calculated at the brightness of CIECAM02 in typical viewing situations and derived from a quantification of two mutual information between white and black.

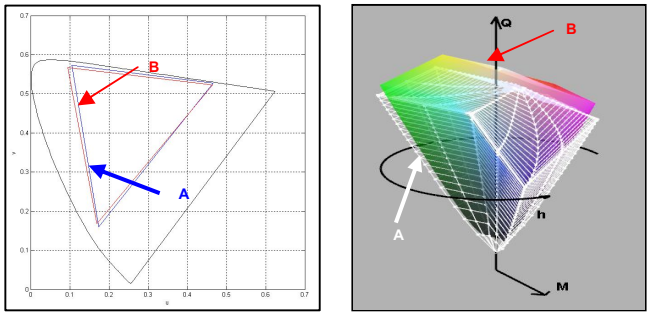
3. Results

3.1 Color reproduction capability

We compare the performance of color gamut volume against color gamut area. Table 1 presents comparisons between displays. The fitting of the primary colors to *u'v'* and brightness of CIECAM02 calculating surface color points of primary colors with, black and white is shown in Fig.2. In *u'v'* coordinates, an area of B is bigger than A, but a volume of A is bigger than B, according to color coordinates of dim area. It is important to get low black intensity of display, since the sphere from black to primary colors occupies most of the volume in color space. The size of volume characterizes the sensitivity of the visual system as a function of color reproduction capability. It is generally acceptable for the competition to stable evaluate emotional image quality within the appearance modeling, since modeling can be compensated for adaptations. Moreover, since the modeling is likely to depend upon the subjective brightness scope. A Color reproduction capability is dependent on the volume of color space.

TABLE 1. Compare the areas of color

Display	Area of *u'v'* coordinates	Volume of Color Space
A	0.0729	2,325,502.95
B	0.0720	2,122,971.77



(a) (b)

Fig. 2. Comparison between A and B: (a) area in *u'v'* coordinates, (b) volume in brightness of CIECAM02 coordinates

3.2 Perceptual contrast

We calculate a new approach to contrast where we quantify the range between black and white brightness, and demonstrate that this quantification relates well with visual quality. Mutual brightness information can be calculated on the luminance component of the display and surround condition since stimuli brightness are affected by other side intensity that are nearby in background and surround[6]. In Table 2, the fixed white luminance is typically applied to calculate perceptual contrast range, which can be compared against the absolute contrast as being the numeral information with the various black luminance levels.

TABLE 2. Comparison between contrast ratio and contrast range

Absolute Contrast	White [cd/m^2]	Black [cd/m^2]	Perceptual Contrast	
			range	ratio
1,000:1	303.1	0.3	201.994	1.000
10,000:1		0.03	222.654	1.102
100,000:1		0.003	234.589	1.161
1,000,000:1		0.0003	241.480	1.196

Though the contrast increases with black luminance, and black and white are not controlled by each other,

it is difficult to identify changes in proportion to the increase. On the other hand, white and black brightness are changed by mutual influences and an increment contrast range is similar to human sensitivity.

In Table 3, it is shown that the absolute contrast of LCD and AMOLED is 333:1 and 21,000:1 each other and the AMOLED is almost 63 times as contrast between the AMOLED and the LCD, though luminance of AMOLED is lower than LCD. In table 4, a perceptual contrast range, which is evaluated brightness of CIECAM02 considering human perception, of LCD and AMOLED is 181 and 205 each other and the AMOLED is 1.13 times. Also we demonstrate that luminance of AMOLED is extracted to quantify the same contrast range with LCD, the test image, which is being viewed, is similar to between AMOLED and LCD. We find that for same contrast range AMOLED and LCD as 181, luminance of AMOLED and LCD are 110 cd/m^2 and 250 cd/m^2 respectively.

TABLE 3. Contrast of displays

Display	Luminance		Contrast Ratio
	White	Black	
LCD	256.3	0.77	333:1
AMOLED	189.9	0.009	21,100:1

TABLE 4. Comparison of perceptual contrast

Display	Brightness		Contrast Range
	White	Black	
LCD	242.35	61.67	181
AMOLED	227.85	22.83	205

4. Discussion

We investigate the emotional evaluation with color reproduction capability and perceptual contrast range. The color reproduction capability, which is derived from a color appearance model for color reproduction, outperforms traditional color gamut in this experiment. And the perceptual contrast range presents human judgment between quantified white and black brightness. We are continuing efforts into extending evaluations of emotional image quality for an approach of human visual experience using the color appearance model. Moreover we expect a quantitative evaluation of an emotional image quality to be standardized.

5. References

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