P-57: Color Shift Evaluation in Motion Image

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Abstract

Motion color images in LCDs become more and more important topic. In this paper, a color shift evaluation method is examined to judge the quality of captured motion images via a pursuit camera system. Furthermore, fifteen expectative color mixtures of color pairs were compared with results of subjective tests. Experiment results revealed that there exists high correlation between measuring system and the subjective test, and the proposed method was enough to be a quality index to present color shift characteristics for LCD displays.

1. Introduction

Nowadays, the liquid crystal display (LCD) has become the most popular display device. A lot of discussion for Motion Picture Response Time (MPRT) had been proposed to measure the quality of motion blur image at LCDs [1][2][3]. The discussion of MPRT had taken into account all gray levels response time, but not for color image. The color motion blur response at the liquid crystal seems only the voltage control and could reduce as the change of luminance. However, the color motion picture in the human eye is not only the change of luminance, but also the change of hue, chroma, and so on. In these colors shifting region, what can be seen in the human eve is one of targets in this research. We design an experiment to evaluate the color shift in the motion images, and propose a measuring method using the Pursuit Camera System (PCS) to present the quality index of color shift. According to the preliminary results, the correlation of human eye behaviors and proposed expectative color is high enough. In the other words, expectative color can be used to stand for the human response of color motion images.

The remainder of this article will be described as follows: In Section 2, we describe the method of subjective test and the analysis strategy for pursuit images. The comparisons of subjective test results and CSI is demonstrated in Section 3. Conclusions and future works are presented in Section 4.

2. Methodology

Four different level of response time of 17" LCDs are used in this research. We have designed a subjective test to investigate what color would be seen in the blur edge of moving object. Then we used the developed pursuit camera system to capture the image of blur edge and analyze that image to obtain the expectative color that should be the color human seen.

2.1 Subject Test

There are four kinds of 17" LCD (ViewSonic VA720, ViewSonic VP171s, ViewSonic VP730b, SAMSUNG 730BF) with different levels of response time, 25ms, 16ms, 8ms and 4ms respectively. The surround of experimental environment is dark. The viewing distance from display is 500 mm. The rectangle of 100×595 pixels was set to foreground color, and move from left to right at speed of 10 pixels per frame on background color. Seven color blocks

for color shift scale were generated and calculated by a linear regression formula based on the background color to the foreground color. The size of those seven color chips is square of 100 pixels and shown on the top of screen. Figure 1 illustrates an example of the stimulus from Red color to Green color in this experiment. In this study, six primary and second colors would be set to background and foreground color. 15 pairs of color combination would be set with single ratio of chroma. Those pairs were R-G, R-B, R-C, R-M, R-Y, G-B, G-C, G-M, G-Y, B-C, B-M, B-Y, C-M, C-Y and M-Y. Moreover, the 4 levels of chroma would be equally separated, in other words, those colors are 25%, 50%, 75% and 100% ratio of chroma, respectively.



Figure 1. The experimental window of subject test

2.1.1 Subjects and Experimental Task

The voluntariness participants, in this study, were 70 students with normal vision by using convenient sampling.

Total of 240 trials were being randomly set from four chroma levels multiply 15 color combinations on four kinds of LCD. Subjects were requested to track and to focus on the left side of moving bar to the best of their ability. Then subject had to answer where the color shift was close to which seven color chips for scaling. In addition, subject also could guest the color shift locating between two color chips. The experiment design was a with-in subject design.

2.1.2 Data Collection and Analysis

Analyses of variance were used to detect significant difference among levels of chroma, colors and LCDs. Data were collected primarily by means of self-report with score that was target color by subjects after viewing. The score set from 1 to 7 were being from background color to foreground color. Using the linear regression formula, the score can be used to calculate the target color. Color different (ΔE) would be calculated between target color and foreground color with CIEL*a*b* value. Consequently, the target color was similar to foreground color when color different was small. Contrariwise, the target color was similar to background color when color different was large.

2.2 Pursuit Camera System

The pursuit camera system has been implemented to capture an image which is similar to the previous study [3]. According to human vision characteristics, an image that is captured by our pursuit camera system is a result of temporal continuous image integration with simulated eye movement which is synchronized with motion picture. A test pattern (foreground) is a color block, which is scrolled on a display (background). A test pattern on a display present the color pair that the same as subjective test.

It is shown the design of the pursuit camera system in Figure 2. The size of a display panel is $W \times H$, and the measuring distance is around three times of display height. The moving speed of a test pattern is 10 pixels per frame. The pursuit camera traces a test pattern in a range of rotation angle.



Figure 2. Pursuit camera system structure

The image that captured by the pursuit camera system is analyzed into $L^*a^*b^*$ channels as shown in Figure 3. Based on these profiles, the foreground and background colors could be decided at the stable region. Each color pair can calculate the 5 candidates color (CC) between the foreground color (CF) and background color (CB) by equation (1).

$$C_{C} = \alpha \cdot C_{F} + (1 - \alpha) \cdot C_{B},$$

$$\alpha = \{0.0, 0.125, 0.3, 0.5, 0.7, 0.875, 1.0\}$$
(1)

Figure 4 is an example of Blue-Cyan color pair, and presents the CF, CB, and 5 candidate colors. The captured image with the pursuit camera system is shown in Figure 5. The color between CF and CB in the Figure 5 all display in Figure 4, where red points denote the measured chromaticity value in CIELAB color space. In the color shift region, the expectative color that will be seen in the human eye should occupy more pixels in the capture image than other colors. For this reason, the color points between CF and CB are decided to belong to which candidate color. After

that, we can see that which candidate color have the most color points. In the other words, this candidate color occupy largest region in the motion blur area. Therefore, the average of this candidate color should stand for the color that will be seen in the human eye. Unfortunately, the human eyes more focus on the foreground (moving pattern) than background. We set the weighting value to each candidate color, the closer to CF, the more weighting value is. The expectative color can be calculated by equation (2).

$$C_{\text{expect}} = \sum_{i=1}^{5} \omega_i C_{candidate}^i$$
(2)

where ω is the weighting value for each candidate color.



Figure 3. The L*a*b* profile of Blue to Cyan color pair. The red, blue, and green lines present the profile of luminance (L*), a*, and b*. The value of X-axis is the position of captured image.



Figure 4. The Blue-Cyan color change shown in the L*a*b* color space. These seven color squares represent the transitions from foreground color (blue), background color (cyan), and 5 candidate colors.



Figure 5. The color pair of Blue-Cyan image which was captured by pursuit camera system.

3. Experimental Results and Discussion

Here four LCDs are chosen to evaluate the color motion blur effect. All the color setting is the same as the subjective test and the analyzed results are shown in the Appendix. The expectative color is calculated by Eq. (2) for each color pair and shown on the green square at each color pair of the Appendix. The color differences (ΔE_{ab}) between the expectative color and foreground color of each color pair are listing in the **PCS** columns of Table 1. The **Human** columns list the color difference results of subjective test. The regression line of the subjective testing value and PCS value is shown in the Figure 6. The R^2 of this regression line is 0.9045, in the other words, the correlation between the subjective test and our PCS is very high.



Figure 6. The correlation of the regression line is 0.9045.

Although the whole correlation between the target color of the subjective test and the expectative color is high enough, the individual correlation is not as better as that. According to the different ratio of chroma, the correlations were calculated respectively. The worst case of the correlation appeared in the case of 50% ratio of chroma, as shown in Figure 7. The \mathbf{R}^2 of this regression line is only 0.725. The most separated point of these data was marked as red circle in the Figure 7. This point was the color pair of Green-Magenta. In the Appendix, the color pair of Green-Magenta is shown in the column 3 and row 2. We can see that the curve of the PCS's data are the more separated to the color shifting line than other color pairs. Consider the other ratio of chroma, the color pair of Green-Magenta is also the most separated point. If we take the Green-Magenta data away, the \mathbf{R}^2 of the regression line of 50% chroma will become to 0.8394, and the \mathbf{R}^2 of the whole regression line can reach to 0.9263. The change of RGB channel of color shifting from Green to Magenta is (0, 1, 0) to (1, 0, 1). It means that the whole three liquid crystals in one pixel change their state in the blur edge. Another worse

case is the color pair of Blue-Yellow (shown in the column 2 and row 3 of Appendix). We can see that the curve of the PCS's data is also separated to the candidate colors and the change of the liquid crystal of each sub-pixel the same as the situation of the color pair of Green-Magenta. Although this could be the reason that the expectative color is not close to the color human seen, we will still study this topic in the future.



Figure 7. The worst case of the correlation of the expectative color and subject test appeared in the case of 50% ratio of chroma.

4. Conclusion and Future Work

We have proposed a Pursuit Camera System (PCS) to capture the motion image with simulated human eye movement. Furthermore, the color shift evaluation method is presented to calculate the expectative color. According to the regression analysis result, the correlation of the subjective test and our evaluation method is good enough.

Assign the weighting value to each candidate color is a critical factor during explaining where human eye focused. Not only considering the amount of points in every candidate color, but also the distance from the foreground color should be taken into account. In the future, based on these weighting values, a model takes account of human visual perception will be examined further.

5. Acknowledgements

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6. **References**

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chroma	100%		75%		50%		25%	
	Human	PCS	Human	PCS	Human	PCS	Human	PCS
RG	81.33	64.89	60.38	53.03	42.06	33.97	27.21	19.69
RB	64.42	63.74	47.4	52.7	31.44	35.71	17.88	19.22
RC	54.52	60.05	53.92	49.18	38.06	33.24	24.76	20.64
RM	41.39	46.26	30.68	37.13	21.81	22.85	10.9	10.13
RY	51.39	40.59	39.18	34.56	32.03	29.51	24.3	24.71
GB	111.28	94.47	78.89	76.99	52.85	54.32	29.49	33.38
GC	37.52	38.4	26.47	29.7	17.41	19.41	9.31	7.73
GM	79.18	87.19	51.94	68.6	31.96	45.72	13.76	19.92
GY	25.37	27.11	21.68	22.62	15.51	17.39	8.367	12.43
BC	57.17	55.48	50.84	48.14	45.66	37.37	34.46	26.54
BM	30.64	22.54	22.48	19.4	16.88	15.79	17.96	14.99
BY	84.16	83.45	70.21	62.82	57.7	45.41	41.58	33.26
СМ	49.4	58.49	36.76	47.49	23.95	31.62	10.23	14.83
CY	47.73	43	33.72	32.58	27.15	25.38	12.1	11.44
MY	75.41	72.69	66.12	54.39	47.04	36.07	22.46	16.66

Table 1. The color difference of all experimental setting

Appendix: Captured images and color transitions in experiments

