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SPEED VERIFICATION FOR TWO-COLOR SWITCHING WITHOUT FLICKER

Chikako Ishizawa† Shogo Kitano†
Yoichi Kaeyama† Makoto Nishida†
†Graduate School of Engineering Science, Akita University, Japan

ABSTRACT

The objective of this study was to develop a method to display a desired color through the switching of two colors on a liquid crystal display (LCD). However, if the switching speed is slow, a flicker may occur that can disturb viewing. In this study, we determined whether a flicker occurred under the conditions of three speeds (100 Hz, 120 Hz, and 144 Hz) to ascertain if the switching speed was required to mix two colors without a flicker on an LCD. The results showed that a switching speed of more than 120 Hz was required to mix the colors that were used in the experiment without causing a perceptible flicker.

1. INTRODUCTION

Owing to the widespread use of digital and mobile phone cameras, photography has become a ubiquitous activity. However, illegal photography using such devices has generated certain social problems. For example, copyright infringement cases have occurred in which the movie scenes broadcasted on television are captured by a digital camera, and the resulting image files are posted on the Internet [1].

On the other hand, when two different colors are switched at a high speed, it becomes impossible for a human to distinguish them, and the color resulting from the mixing of two original colors can be perceived. This color mixing is called successive additive color mixing [2]. Displaying these colors on an LCD by using successive additive color mixing may be applied to protect a displayed image. When images of red and green color are switched, as shown in Fig. 1, a yellow image will be perceived.

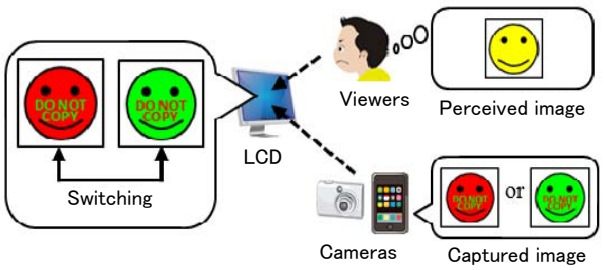

Figure 1. The copy protection of images achieved by switching two colors.

However, a photograph of the image will show red or green. Thus, the displayed image cannot be properly captured.

The LCD screen is rewritten 60 times per second (60 Hz) based on the human visual characteristics. Thus, it is considered that the switching speed exceeds 120 Hz to mix the two colors. On a cathode ray tube (CRT) monitor, the switching speed over 100 Hz is required for two-color mixing [3]. However, no examples exist of executing successive additive color mixing on an LCD.

The displaying mechanism of the LCD is different from the CRT. In the CRT, a color is displayed by hitting the electron beam gun against the fluorescent substance which is applied inside of the front glass. On the LCD, a source of light is put behind the RGB filter, and the transmission light quantity of the filter is decided by a twist of liquid crystal controlled electrically. The speed for changing the twist of liquid crystal is called response speed and is slower than the controlling speed of the electron beam. However, the response speed of the LCD has been improved. The response speed of 8 ms is necessary for switching of two colors at 120 Hz. Recently, the LCD having the response speed exceeds 8 ms is made. Thus, it is considered that successive additive color mixing is also possible on an LCD.

It is known that the flicker will occur when two colors with different brightnesses are switched. In Japan, an accident that the blinking of lights in the animation broadcasted on the TV caused the photosensitive epilepsy seizure to an audience occurred in 1997 [4]. As a result of investigation, it became clear that the blinking of the strong red light and the blue light at 12 Hz caused the photosensitive epilepsy seizure [5]-[7]. Additionally, the guidelines on video techniques such as animation were created by The Japan Commercial Broadcasters Association and Japan Broadcasting Corporation [4][8]. The proposed method in this research should also avoid the risk of the photosensitive epilepsy seizure. Thus, we assessed whether a flicker occurs when two grayscale images of different brightnesses are changed at a speed of approximately 120 Hz.

2. EXPERIMENTAL METHOD

The specifications of the LCD (ASUS VG248QE) used in the experiment are listed in Table 1. The LCD was the monitor used for games to compete for speed, and the response speed was high. Refresh rates of 100 Hz, 120 Hz, and 144 Hz were respectively used in the experiment.

Table 2 shows the colors employed for switching. A grayscale was used to check whether the switching speed and color brightness related to the occurrence of the flicker.

Two colors were obtained from the grayscale of nine types that changed in gradation (RGB values) by 32 steps. Thirty-six types of combinations of colors were obtained in total.

The size of the image displayed through the switching was 640 × 480 pixels. The image was placed in the center of the halftone gray screen to reduce the influence of the neighboring color on viewing the image.

The test subjects were 19 healthy individuals (15 males and 4 females in their twenties, all Mongoloids). The distance between the test subjects and the LCD was approximately 60 cm. The assessment standards for the flicker were the following:

(a) No flicker is perceived. The image appears the same as the static image.

(b) A flicker is perceived. The image does not appear the same as the static image.

The experiment was conducted under standard light sources (D65). To gain an understanding of the adverse bodily effects, such as a headache or dizziness, a simulator sickness questionnaire (SSQ) [9] was used before and after the experiment. Data collections were conducted based on the Ethics Standards Pertaining to Research Intended for Humans of Akita University.

The luminance of the colors employed for switching was measured using by a colorimeter. The specifications of the colorimeter (KONICA MINOLTA CL-200) used in the experiment are listed in Table 3. The colorimeter was put to contact with the LCD screen and the circumference of the light receiving window was covered by a black visor of the opacity to block any environmental light. Therefore only lights output from the LCD were measured.

Table 1. Specifications of the LCD used

Panel size	24 in
Resolution	1,920 × 1,080 dots
Response speed	1 ms
Refresh rate	60 Hz / 100 Hz / 120 Hz / 144 Hz
Maximum luminance	350 cd/m^2

Table 2. RGB values of the colors used for switching

(0, 0, 0)	**(95, 95, 95)**	**(191, 191, 191)**
(31, 31, 31)	**(127, 127, 127)**	**(223, 223, 223)**
(63, 63, 63)	**(159, 159, 159)**	**(255, 255, 255)**

Table 3. Specifications of the colorimeter used

Receptor	Silicon photocell
Relative spectral response	Closely matches CIE standard observer curves x(λ), y(λ), and z(λ) within 6 % (f1') of the CIE spectral luminous efficiency V(λ)
Measuring range	0.1 to 99,990 lx (5 lx or above) in four automatically selected ranges
Response time	0.5 sec. (continuous measurement)

3. RESULTS AND DISCUSSION

3.1. Switching speed and flicker

Figure 2 shows the number of the color set perceived as having no flicker. The red bar indicates that the color set of more than 80% of test subjects perceived no flicker. It is evident that the red bar increases with the increase of the switching speed. The light blue bar indicates the color set for which fewer than 20% of test subjects perceived no flicker. The light blue bar is decreased with the increase of the switching speed; moreover, it does not exist at 144 Hz. This result suggests that the set of two colors can be mixed without flickers by the switching speed over 120 Hz.

As a results of the simulator sickness questionnaire, there were no subjects who caused a physical condition change, such as a headache or dizziness. Most of subjects who perceived a flicker at the switching speed of 144Hz answered that "the edge of the image appears to be moving".

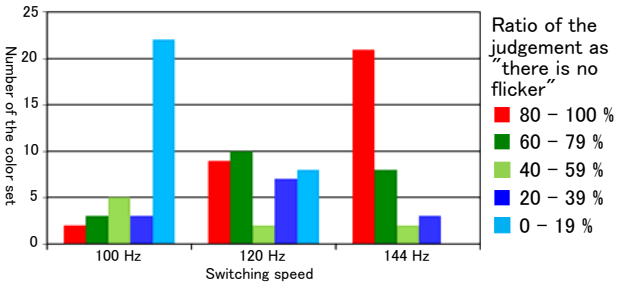

Figure 2. Percentage of the color set in which no flicker is perceived.

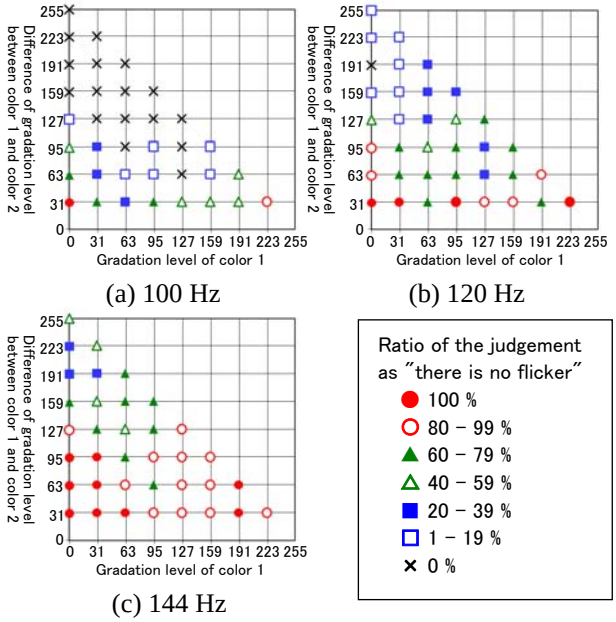

Figure 3. Relationship between the percentage of assessments perceiving no flicker, and the brightness of colors used for switching.

3.2. Brightness of the color and flicker

Figure 3 show the relationship between the number of the assessment of no flicker being perceived and the brightness (gradation level) of colors used for switching. The two color sets of gradation at levels 0 and 31, and at 223 and 256, did not cause a flicker at any switching speed. To prevent the photosensitive epilepsy seizure, the guidelines on video techniques such as animation stipulates “the area where blinking occurs must not exceed 1/4 of the screen” and “the luminance change must be kept to 10 % or less” [8]. The experimental area where blinking occurs conformed to the guidelines. However, the luminance change of two colors were about 91.1 % (the set of gradation at levels 0 and 31) and 23.4 % (the set of gradation at levels 223 and 256), respectively. Since human eyes do not distinguish too bright or dark colors well [2], it is considered that the flicker was not perceived even if the luminance change exceeds 10 %.

Except for the above two sets, the flicker decreased with the increase of the switching speed. When the switching speed was 144 Hz, most of the sets with a difference of gradation level of 127 or less did not cause a flicker. The luminance change of each sets were about from 12.0 % to 69.4 %. On the other hand, even if the difference of the gradation level between two colors was 127 or less, the set of intermediate gradation level caused the flicker (see the triangle plot in Figure 3 (c)). There are believed to be two reasons for the above issue. One is that human eyes are able to distinguish middle colors well [2]. The other is that the speed required for changing a middle gradation color decreases with the LCD. Thus, it is necessary to make two colors have a similar brightness to display the middle gradation color through switching.

The above results suggest that it is difficult to display all colors without flicker by the switching two colors on the LCD, but it is possible to display the limited colors under the certain conditions.

4. CONCLUSION

In this paper, we presented a verification of whether a flicker occurs when switching two grayscale images of different gradation levels at speeds of 100 Hz, 120 Hz, and 144 Hz. The results showed that color mixing is possible without flickers when the combination of two colors with a difference in gradation level of 127 or less are switched under a speed that must be faster than 120 Hz.

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REFERENCES

[1] Japan and International Motion Picture Copyright Association, Inc., http://www.jimca.co.jp/news/index_e.php (accessed 13 Jan. 2017) .

[2] Vision Society of Japan, Visual Information Processing Handbook, Asakura Publishing Co., Ltd. (2000).

[3] K. Shioda, E. Yoshida, M. Soga, A. Takubo, K. Hayashibe, I. Nakamura, T. Mizuno and M. Nishigaki: “Digital Image Content Protection Using Human Visual Performance Characteristics,” Transactions of Information Processing Society of Japan, Vol. 46, No. 8, pp. 2078-2097 (2005).

[4] Ministry of Internal Affairs and Communications, http://www.soumu.go.jp/main_sosiki/joho_tsusin/policyreports/japanese/papers/press/Japanese/Housou/0626J12.html#200 (accessed 13 Jan. 2017).

[5] T. Takahashi: “EEG diagnosis of photosensitive seizures and its preventive measures,” The Journal of the Vision Society of Japan, Vol. 17, No. 1, pp. 49-55 (2005).

[6] T. Morita: “Development of technology to prevent influence of images upon viewers,” The Institute of Electronics, IEICE technical report, Vol. EID2006-25, pp. 11-16 (2006).

[7] S. Katsuki: “The Risk of Photosensitive Epilepsy and Some Latest Trends about Noteworthy Video Techniques for Producing TV Programs,” ITE technical report, Vol. 38, No. 21, pp. 21-28 (2014).

[8] The Japan Commercial Broadcasters Association, https://j-ba.or.jp/category/broadcasting/jba101033 (accessed 13 Jan. 2017).

[9] I. Tsubaki, T. Morita, K. Aizawa and T. Saito: “Image Conversion Methods to Prevent Discomfort Flickers,” The Transactions of the Institute of Electronics, Information and Communication Engineers D, Vol. J89, No. D-7, pp. 1606-1609 (2006).