A study on the Increase of Perceivable Information in the Saccade with High Speed Line Display

Naoki Kawasaki[1], Yuuki Machida[1,2], Takayuki Misu[1,3], Keiichi Abe[1,4], Hiroshi Sugimura[1,5], Makiko Okumura[1,6],

naokikawasaki2020@gmail.com

[1] Kanagawa Institute of Technology Kanagawa, Japan and 1030 Shimo-ogino, Atugi, Kanagawa, 243-0292, JAPAN

Keywords: Line display, flashing frequency, perceivable pixels

ABSTRACT

In this paper, a high speed flashing line display was developed using a CPLD and PIC microcontroller, and the relationship between the flashing frequency and the optimum distance that can be perceived with the least distortion was clarified. The results show that the higher the flashing frequency is, the more information can be perceived from a farther position.

1 INTRODUCTION

We frequently move our eyes to the object of interest in our lives. The fast eye movement occurring at this time is called a saccade, which is a fast and short-lasting eyeball movement with an average angular velocity of 300-500 deg/s and a duration of about 30-80 ms[1]. A line display using this saccade has been proposed[2][3]. When an observer moves his or her eyes across a one fixed dimensional line display, a series of linear images produced by vertically dividing an image to be displayed are sequentially flashed at high speed, whereby the two-dimensional information is perceived on the retina by the eyeball movement and the flashing vertical pattern appears to be expanded horizontally. Saccadic suppression of the retinal image causes a deterioration of the visual characteristics[1]. Saccadic suppression is less likely to occur in an image with many high spatial frequency components and color stimuli[4][5]. Darker backgrounds also moderate the saccade suppression [2][6]. Therefore, information can be easily perceived in the dark environment such as outdoors at night. On the other hand, the technology called persistent of vision (POV) or versa-writer has been used for a long time as a method of presenting two-dimensional information by using the after-image from the fixed one-dimensional flashing point sequences. In this case, a large space and high power are required to move the device, but in the case of a line display, the human retina perceives the after-image on a single line. Therefore, this system can display information without moving the device, and is expected to be useful for nighttime advertisements and lighting for entertainment, such as illumination.

An earlier study reported on the temporal relationship between the size of the perceived image and eyeball movements in a similar device [7]. In reference [8], a method of creating content images based on perceptual characteristics by saccades was proposed, in which the flashing frequency of the device was set to 2 kHz. We have been studying and developing line displays, and our previous studies have clarified the relationship between the flashing period of one line and the angle of eyeball movements [9]. We also developed a line display driving 64 LEDs and conducted experiments to evaluate the size of the image for the flashing period using saccade[10]. With respect to grayscale of displayed images, a 5- gradation image was displayed by the fastest flashing period of 42 μs[11]. In the previous experiments, the distance between the device and the subject was fixed at 2 to 3 m for domestic use. However, it is required to be visible from a larger distance for outdoors use at night such as advertising.

In this paper, we have developed a fast flashing line display with 20 μs, and by varying the distance between the subject and the display, we have clarified the relationship between the distance and the flashing frequency that can be perceived with no visible distortion. We have also verified that the number of pixels and color gradation can be increased with the high speed flashing.

2 Development of High Speed Flashing Line Display

In this paper, a line display is created using a complex programmable logic device (CPLD) and a PIC microcontroller in order to shorten the data transfer time. It consists of a microcontroller board that transfers data and four sub-boards, where each sub-board drives 16 LEDs, as shown in Fig. 1. It was designed to enable the connection of five or more sub-boards using a comparator.

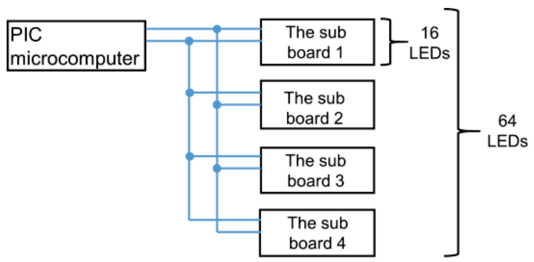


Fig. 1 Configuration diagram of Line display

Fig. 2 shows the sub-board configuration and Fig. 3 shows the timing diagram. The data transferred in 8 pixels divided into 24 times is held in the latch circuit, and after all the data is completely transmitted, it is sent to the transistor arrays all at the same time. The latch circuit that holds the data, the comparator for selecting the sub-board and the decoder were designed using the CPLD. The PIC24EP512GP204 is used as the microcontroller.

The pattern diagram of the sub board designed by CDA software Eagle and the developed sub-board are shown in Fig. 4. The board was 122 mm long (16 LEDs) and 100 mm wide. A developed line display with four sub-boards and a microcontroller board is shown in Fig. 5.

Figure 6 shows the result of measuring the fastest flashing period with an oscilloscope. The fastest flashing period is 20 μs, which is more than twice as fast as the device developed in our previous work (42 μs)[11].

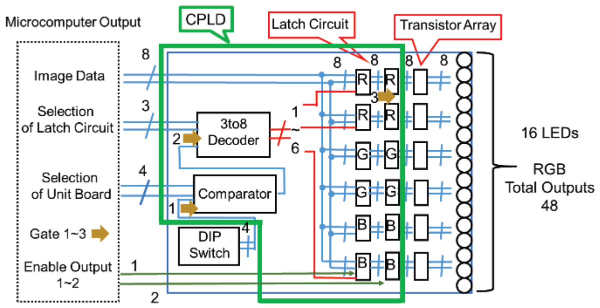


Fig. 2 Configuration diagram of the sub board

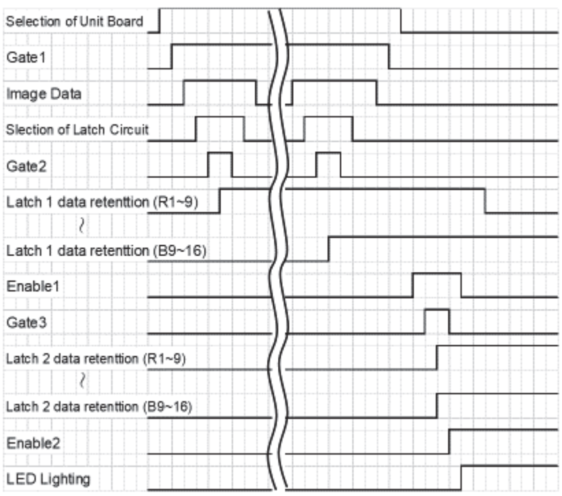


Fig. 3 Timing diagram of data transfer for LEDs

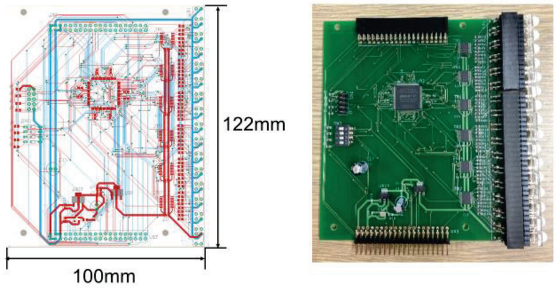


Fig. 4 Pattern diagram designed by CDA software Eagle and the developed sub-board

Fig. 5 Developed line display

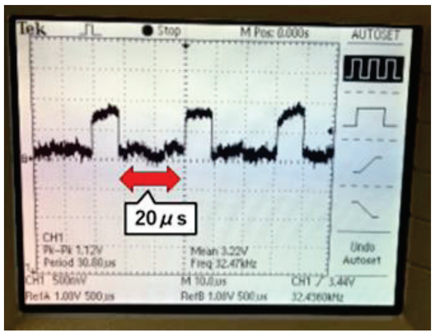


Fig. 6 Observation results by the oscilloscope

3 Increase in the number of shades due to high speed

A PWM waveform is generated to create multiple gradations. Assuming a flashing period T and a data transfer time of td, the gradation G = T/td+1, therefore, if the data transfer time is 20 μs and the most visible flashing period is 0.3 ms[11], the gradation can be increased to 16 levels. A photograph of a person with multi-shaded colors displayed with a flashing line display is shown in Fig. 7, with the original image and 16 and 5 grayscales. This picture was taken by moving a digital camera to simulate eyeball movements. By increasing the number of grayscales, the contours of the face become more distinguishable from the background, and the image of the face is displayed more clearly.

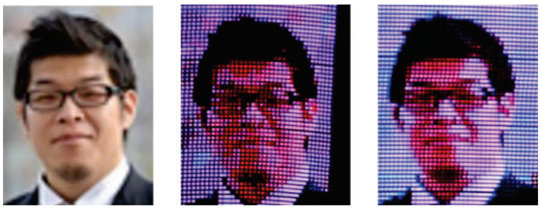


Fig. 7 Displayed gray scale images by our developed line display

4 EXPERIMENT

The experiment was conducted to evaluate the flashing period and perceivable distance of images. The experimental condition is shown in Fig. 8. The experimental environment was outdoor at night, the illumination was 0.9 lx, and a 64x64 pixels yellow star image. The evaluation criteria for image perception are shown in Fig. 9. Four subjects (S0-S3) were tested to measure the distance L, which is the optimum distance to perceive the displayed image with the least distortion, at each flashing period. The experiments were conducted with a flashing period ranging from 0.05 ms (20 kHz) to 0.3 ms (3.3 kHz).

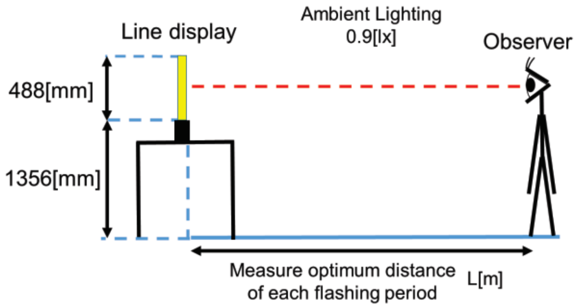
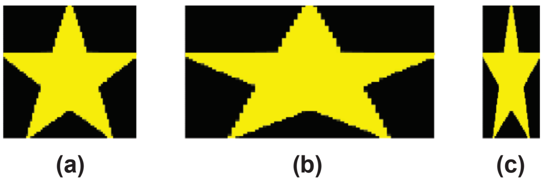


Fig. 8 Experimental condition for optimal distance



(a) Original image
(b) Horizontal distorted image
(c) Vertical distorted image

Fig. 9 The evaluation criteria for image perception

5 RESULTS

The measurement results of the four subjects (S0-S3) and their average values are shown in Fig. 10. The vertical axis is the perceptible distance and the horizontal axis is the flashing frequency. The results showed that the optimal distance for perception was longer as the flashing frequency was higher, and shorter as the frequency was lower. When the flashing frequency was 20 kHz, the maximum and minimum values were 19.1 m and 11.4 m, respectively, and the average value was 15 m. As the flashing period was decreased, the visible distances became shorter, with a maximum of 4.0 m, a minimum of 2.6 m, and an average of 3.3 m at 3.3 kHz.

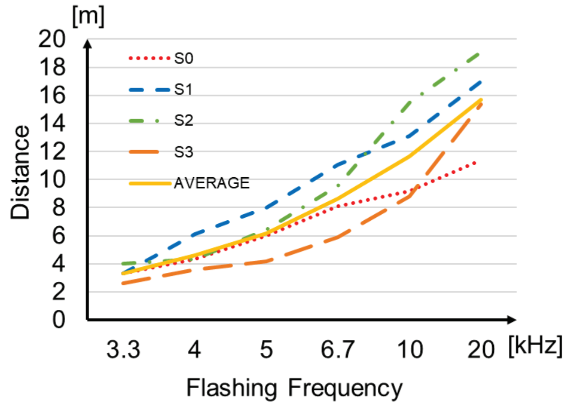


Fig. 10 The relationship between flashing frequency and optimal distance

6 DISCCUSION

According to reference[12], when the saccade amplitude is θ [deg] and the size of the light source in the field of view is D [deg] (for example, D = 0.1 deg for an LED with a light source of 5 mm observed from 3 m away), the maximum number of horizontal pixels X that can be displayed is given by the following equation.

$$X = \theta / D \quad (1).$$

Let ℓ be the distance the light source moves on the retina during the flashing period tm, then

$$\ell = V \times tm \quad (2).$$

Where V is the eye velocity in saccades. When the moving distance on the retina ℓ is larger than or equal to the light source size D ($D \leqq \ell$), the lights can be perceived without overlapping, and particularly when the size is the same as the light source ($D = \ell$), the information can be perceived without distortion. When θ is constant, the maximum number of pixels X depends on D. When V and tm are constant, D is relevant for presenting information with less distortion. The size of the light source D is given by the following equation.

$$D = L \times \tan\ell \quad (3)$$

where L is the optimal distance between the device and the subject. From equations (2) and (3), assuming a velocity V, we have calculated the optimal visual distance L for each flashing period at $D = \ell$, and compared it with the average of the measured values. Optimal distance and measured values on flashing frequency are shown in Fig. 11. In the estimated model, the eye velocity V during saccade was assumed to be 250 deg/s and the angle was 10 [deg], based on the relationship between saccade amplitude and maximum velocity [1]. Fig. 11 shows that there was a slight difference between measured and calculated values of estimated model around 20 kHz, but it shows almost the same tendency from 10 kHz to 3.3 kHz. Figure 12 shows the result of calculating the maximum number of pixels for each flashing frequency from equation (1) using the optimum distance for each flashing frequency in the experimental results. It shows that the number of perceivable pixels increased as the distance and the flashing frequency increased.

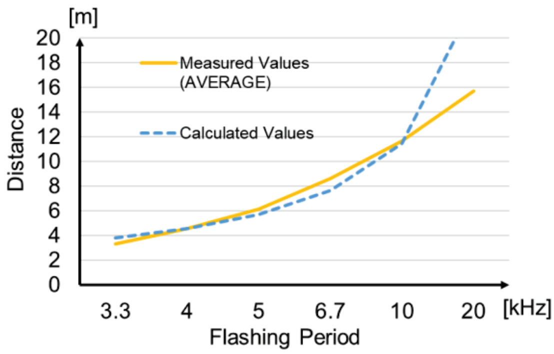


Fig. 11 Optimal distance and measured values on flashing frequency

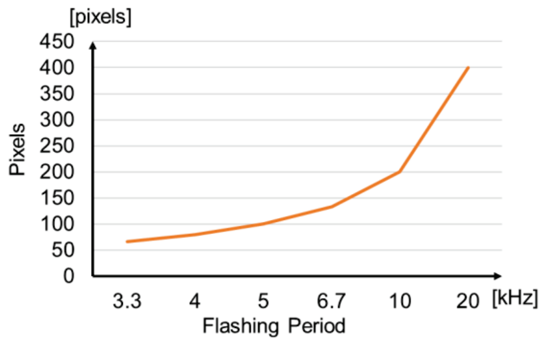


Fig. 12 Perceivable pixels depending on flashing frequency

7 CONCLUSIONS

In this paper, a high speed flashing line display with variable flashing is developed using a CPLD and PIC microcontroller. The maximum flashing period is 20 μs, which is more than twice as fast as that of our previous system, and the display of 16 shades of gray is achieved. Experimental results showed that the optimal distance for perception was longer as the flashing frequency was higher, and shorter as the flashing frequency was lower. We have developed a line display that flashes at high speed and is visible at a distance of 15 m or more, which is suitable for outdoors advertisement. We have also confirmed that increasing the flashing frequency allows for the use of a greater number of gradations and pixels to increase the amount of information.

ACKNOWLEDGMENT

We would like to express our sincere gratitude to Mr. Tetsuya Gokan, President of Microchip Design Lab, Inc. for his useful advice. This paper was supported by JSPS Research Grant JP18K04170.

REFERENCES

[1] Vision Society of Japan Editing, “Vision Information Processing Handbook,” Asakura Bookstore, (2000).

[2] J. Watanabe, T. Maeda, S. Tachi, “The Study of Saccade-based Display,” in Japanese, TVRSJ, Vol. 6, No. 2, pp. 79-87 (2001).

[3] J. Watanabe, N. Sakamoto, A. Noritake, T. Maeda, S. Tachi, “Study of Saccade-based Visual Presentation for Moving Viewers,” IEICE, HIP2004-22, pp. 69-73, (2004).

[4] H. Mitsudo, “Saccadic eye movements and perceptual stability”, Faculty of Human-Environment Studies, Kyushu University, Psychological research of Kyushu University, vol. 12, p. 61-68, May, (2011).

[5] K. Uchikawa, M. Sato, “Saccadic suppression of achromatic and chromatic responses measured by increment-threshold spectral sensitivity”, Journal of the Optical Society of America A, vol. 12, no.4, April, (1995).

[6] M. R. Diamond, J. Ross, M. C. Morrone, “Extraretinal Control of Saccadic Suppression”, The Joural of Neuroscience, pp. 3449-3455, May 1, (2000).

[7] J. Watanabe, T. Tavata, T. Maeda, S. Tachi. “Performance with Saccade-based Display,” IEICE Engineering Sciences Society, Technical Committee on Circuits and Systems (CAS), (2019).

[8] R. Aruga, H. Saito, H. Ando, J. Watanabe, “Study on image contents using perceptual properties of Saccade-based display,” in Japanese, TVRSJ, The 13th Congress Proceedings (2008).

[9] K. Kanazawa, S. Kazuno, M. Okumura, “Optimization of Flashing Period for Line Display Using Saccade Eyeball Movement”, The 24th IDW, Japan, pp.1469-1472, Dec 7, 2017.

[10] N. Kawasaki, W. Kyouhei, T. Misu, K. Abe, H. Sugimura, M, Okumura, “Development of Printed Circuit Board for High Speed Line Display Using Eyeball Movement and Optimization of Flashing Period”, in Japanese, IPSJ SIG Technical Reports, Vol. 2019-CDS-26, No9, pp.1-7, (2019).

[11] N. Kawasaki, W. Kyouhei, T. Misu, K. Abe, H. Sugimura, M, Okumura, “Development of High Speed Flashing Line Display Using Eyeball Movement”, IEEE 8th Global Conference on Consumer Electronics (GCCE), (2019).

[12] J. Watanabe, “The Study of Spatio-temporal Integration of Perceptual Characteristics for Visual Information Presentation,” Graduate School of Information Science and Technology, The University of Tokyo, pp. 61-63 (2004).