Considering Temporal Change of Eye Movement for Image Quality Evaluation

J. Bai, K. Hirai*, M. Ukishima*, S. Sano**, T. Nakaguchi*, N. Tsumura*, and Y. Miyake*****

** Graduate School of Science and Technology, Chiba University*
*** Department of Information & Image Science, Chiba University*
**** Research Center for Frontier Medical Engineering, Chiba University*
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

Abstract

In a previous paper, we have proposed an image quality metric by using the gazing information obtained from the measurement of eye movement. In this method, we only consider the spatial change of the gazing information. However, the change of the concentration with time was observed during the subjective evaluation experiment. It is considered that the temporal change of the gazing area is relevant to the importance of the observed gazing area. Therefore, it is necessary to consider the temporal change of the gazing area. In this paper, we measured the eye movement of the observers when they performed the evaluating of the quality of the displayed image on the PDP(Plasma Display Panel) for 15 seconds every 3 second. We analyzed the gazing area of each 3 second. The results show that the gazing area from the first to the third 3 second increases, and it will decreases from the fourth or the fifth 3 second.

Introduction

The increased availability of color imaging systems, computer power and broadband network has changed all of our life as a multi media age. In the multi media age, many kinds of color images have been widely used for e-commerce, medicine, recording, printing and so on. To improve the image quality is the important aim of designing the imaging system[1].

Image quality is one that usually be adjudged subjectively by observers. The subjective evaluation of image is performed by using the paired-comparison method, the five-category scale method, and so on. After that, a statistical processing will be performed follow Thurstone‘s law of comparative judgment. However, the psychophysical experiments are very time consuming and expensive to complete properly[2]. Actually, in designing the imaging system, the effective metric which can predict the perceptual image quality for these image processing methods is expected.

In the image quality evaluation, it is very important to consider the characteristics of human eye. In this paper, we pay our attention to the characteristic of eye movement. When a person looks an object, because the cone cells distribute intensively near the center fossa of retina, he usually moves his eyeballs to let the focus of the objective connected near the center fossa of retina. Therefore, there is eye gaze position (point of regard) when a person looks an object. It is well known that an image has a particular gazing area[3], and in the experimental results and our previous papers[4-6], we found that the total image quality is highly influenced by the gazing area. Also, in a previous paper, we have proposed an image quality metric by using the gazing information obtained from the measurement of eye movement[7]. The effectiveness of the physical quality criterion considering gazing information is verified to be well correlated to the observer rating value. In this method, we only consider the spatial changes of the gazing information. However, the change of the concentration with time was observed during the subjective evaluation experiment. It is considered that the temporal change of the gazing area is relevant to the importance of the observed gazing area. Therefore, it is necessary to consider the temporal change of the gazing area. In this paper, we measured the eye movement of the observers when they performed the evaluating of the quality of the displayed image on the PDP for 15 seconds every 3 second. And then, we analyzed and discussed the change of the gazing area with time.

Measurement of Eye Movement

Observers and Presented Images

The subjective evaluation experiment for measuring eye movement was performed under the viewing condition with 150 lux illuminance as shown in Fig. 1. The color temperature of the used fluorescents (National, FLR 40S-EX-N/M-X 36) is 5000 Kelvin. In this experiment, the

Panasonic PDP (VIERA TH-42PX300) was used for image presentation, the images were 1016×1801 pixels, subtending 9.4°×16.7° visual angle at a viewing distance of 3.1 meters. Figure 2 shows an image example of the test images used in the subjective experiment (other test images are omitted for the problem of the copyright). Ten twenties students, with normal sense of color and visual acuity in our laboratory (eight males, two females) performed the evaluating task by using the five-category scale method. The images were presented for 15 seconds one-by-one, and between each of them a gray image was presented for ten seconds.

Measurement of Eye Movement

Eye position data was collected with the EMR-NL8B eye tracking system (Nac Image Technology Inc). The main components of this system include an eye camera which houses an infrared LED illuminator and a video camera (shown in Fig. 3(a)), a video camera for acquiring the looked scene by observer, a controller, a LED power supply box, and a chin level.

As shown in Fig. 1, the eye camera is placed just below the subject's line of sight. The acquired image by using the eye camera is shown in Fig. 3(b). The infrared, video-based eye tracking system determines the eye position by extracting the center of the subject's pupil and a white point of reflection of the infrared LED illuminator on the cornea and calculating their distance[8].

Analysis of Eye Movement and Experimental Result

Definition of Gaze Position

Because the system is based on NTSC video signals, gaze position is calculated at 60 Hz (video rate). The analyzing software for analysis of the eye movement allows for variable field averaging reducing signal noise. Gaze position (*fixations*) (x, y) is obtained from the eye positions within a given scope over 8 sequent video fields, which yields an effective temporal resolution of 133 msec[9]. The center of gravity of these sequent 8 eye positions is defined as gaze position. In this research, we let the scope be 2-degree visual field.

Gazing Frequency Map

Gazing frequency map is an index that shows the gazed degree. We obtained the gazing frequency map by using a two step procedure.

1. We calculate the normalized spatial gazing frequency $F(x, y)$ at each gaze position (x, y), which is defined by

$$F(x,y) = \left\{ \frac{T(x,y)}{N(x,y)} \right\}_{nol} \qquad F(x,y) \in [0,1] \qquad (1)$$

where, $T(x, y)$ and $N(x, y)$ denote the total gazing time and the number of times of gaze, respectively. The subscript *nol* means normalization.

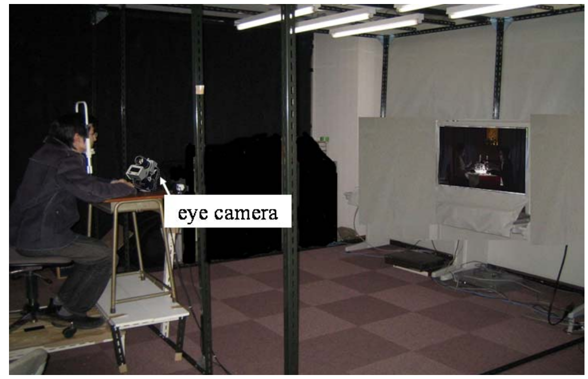
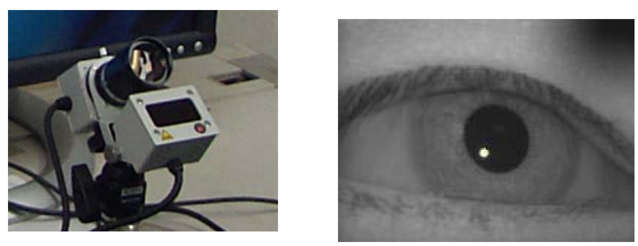


Figure 1. Experiment scenery.

Figure 2. Image example for the subjective evaluation experiment



(a) Eye camera

(b) The acquired image by using the eye camera

Figure 3. (a) Eye camera, and (b) the acquired image by using the eye camera. The white point in (b) is the reflection image of the infrared LED illuminator on the cornea.

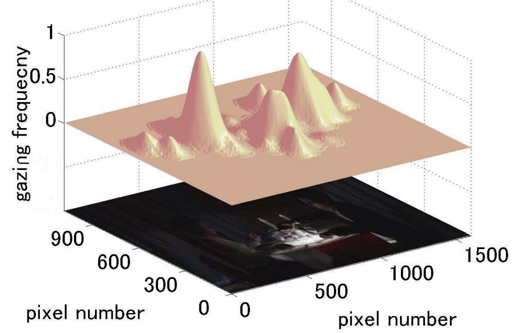


Figure 4. Example of gazing frequency map across ten observers.

(a) Gazing area of the first 3 second from 0 to 3 second;

(b) Gazing area of the second 3 second from 3 to 6 second;

(c) Gazing area of the third 3 second from 6 to 9 second;

(d) Gazing area of the fourth 3 second from 9 to 12 second;

(e) Gazing area of the fifth 3 second from 12 to 15 second.

Figure 5. Changes of the gazing area with time.

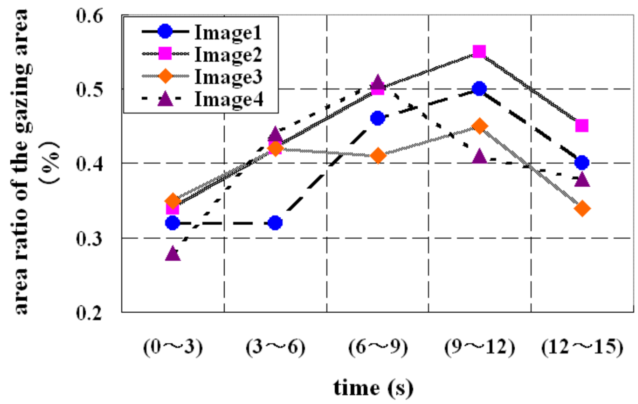


Figure 6. Changes of the area ratio of the gazing area with time.

2. We consider the 2-degree visual fields of human eye by convolving the obtained frequency in step 1 with a Gaussian filter[9]. Because when a person observes an object, not only one point, but also its surrounding is seen simultaneously, the scope including the point and its surrounding is called visual field. In this field, the obtained information decreases if apart from the eye beam[10]. In this research, the integral value of the Gassian filter is defined to be one.

In this way, a gazing frequency map with the consideration of the 2-degree visual field of human eye $F'(x, y)$ can be obtained. Figure 4 shows the normalized gazing frequency maps with the consideration of 2-degree visual field of human eye, the more frequently the area is gazed at, the higher the gazing frequency of an area is.

Gazing Area

The gazing area $\mathrm{G}(x, y)$ is obtained from the gazing frequency map with the consideration of 2-degree visual field of human eye $F'(x, y)$, it is defined by

$$G(x, y) = \begin{cases} 1 & F'(x, y) \geq \theta \\ 0 & F'(x, y) < \theta \end{cases} \tag{2}$$

where, the threshold value θ is within the interval [0, 1]. Here, we let θ = 0. Figure 5 shows the changes of the gazing area with time of the image shown in Fig. 2.

Temporal Change of Gazing Area

The change of the gazing area with time is expressed by the area ratio quantitatively. Area ratio is defined by Eq. (3),

$$A = \frac{P_g}{P_i} \tag{3}$$

where, P_g and P_i denote the pixel number of the gazing area and the pixel number of the whole image, respectively. The change of the area ratio is shown in Fig. 6.

Discussion

As shown in Figs. 5(a) and (b), the gazed area is converged on the small meaningful area, such as the two persons and the glass and the wine on the table in the image. It gradually extends to the surrounding background behind the two persons with time as shown in Figs. 5(c) and (d). After that, as shown in Fig. 5(e), it shows that the gazed area converges on the small meaningful area again.

Figure 6 shows the change of the area ratio with time, the horizontal axis means the interval of time from the first 3 second (1~3 second) to the fifth 3 second (12~15 second). The blue circle shows the area ratio of the image shown in Fig.1. As shown, the area ratio of the second 3 second is almost the same with the one of the first 3 second, and it increases from the third 3 second and decreases at the fifth 3 second. This is corresponding to the change of the gazing area in Fig. 5. From the result, it indicates that the change of the area ratio with time can express the change of the gazing area with time exactly. The change of the area ratio with time of other test images are also shown in Fig. 6, all of them show the same change tendency that the area ratio increases with time and decreases finally.

We explain this result from the psychological point of view, when the observers adjudge the image quality of the presented image, in a general way, they firstly gaze the most interesting area for them (or the most meaningful area in the image). And then they look around the whole image. Finally, before they finish the evaluating task and give the adjudge result, they gaze the most important area they think. It indicates that the more concentrically the area is gazed at, the stronger the relationship between the content in the gazed area and the psychological judgment of the observers is. Therefore, the multiplicative inverse of the area ratio can be used as the index which shows the importance of the gazing area.

Conclusion

The eye movement was measured when the observers performed the evaluating task. The change of the gazing area with time and the change of the area ratio with time were surveyed. It was clear that the change of the area ratio with time can express the change of the gazing area with time exactly. From the results, it showed the gazed area was converged on the small meaningful area firstly, and then it gradually extended to the surrounding background, finally, the gazed area converged on the small meaningful area again. Therefore, we thought that the more concentrically the area is gazed at, the stronger the relationship between the content in the gazed area and the psychological judgment of the observers is. Further the result support the idea that the area ratio can be used as the index which shows the importance of the gazing area. Therefore, in our future work we will introduce the characteristic of the change of the area ratio with time into the metric for display evaluation and discuss its effectiveness.

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Biography of the Principal Author

Jie Bai received the B.S. degree in Thermal Energy and Power Engineering from Huazhong University of Science and Technology, Wuhan, China, in 1996 and the M.S. degree in Electronics and Information Science from Chiba University, Chiba, Japan, in 2001. She is currently pursuing the Ph.D. degree in Information Science at Chiba University. Her Ph.D. dissertation focuses on image processing and image quality evaluation in consideration of the characteristics of human eye. Her research interests include image processing, and image quality evaluation.