ICIC Express Letters
Volume **17**, Number **12**, December **2023**

ICIC International ©2023 ISSN 1881-803X
pp. 1341–1345

FUNDAMENTAL EXPERIMENTS FOR GAZE EVALUATION OF NON-PHOTOREALISTIC IMAGES GENERATED BY NPR

Toru Hiraoka and Mio Isagawa

Department of Information Systems
University of Nagasaki
1-1-1, Manabino, Nagayo-chou, Nishisonogi-gun, Nagasaki-ken 851-2195, Japan
{ hiraoka; bs119002 }@sun.ac.jp

Received January 2023; accepted April 2023

Abstract. *To develop a new method for evaluating non-photorealistic images generated by NPR (non-photorealistic rendering), we consider how to evaluate non-photorealistic images from a physiological aspect and conduct fundamental experiments using gaze motion when looking non-photorealistic images. In the fundamental experiments, two non-photorealistic images are placed side by side, the subject's gazes are tracked using an eye tracker, and subjects are asked to answer which non-photorealistic image looks more beautiful. Then, the relationship between gaze time and the answer to the question is examined. We focus on cell-like images as non-photorealistic images and used cell-like images generated with different parameter values in the experiments. 120 cell-like images generated from 6 photographic images were used for 20 subjects. The results of the fundamental experiments showed that non-photorealistic images that were answered as beautiful tended to be gazed at for longer periods of time.*
Keywords: NPR, Gaze time, Evaluation, Non-photorealistic image, Cell-like image

1. **Introduction.** Numerous studies [1, 2, 3, 4] have been conducted to generate non-photorealistic images using NPR (non-photorealistic rendering). NPR is a CG (computer graphics) [5, 6] technique that renders images with emphasis or omission, like illustrations or paintings. In recent years, various applications of NPR have appeared, making NPR readily available not only on personal computers but also on smartphones and tablets. However, as a method for evaluating the visual effects of non-photorealistic images generated by NPR, subjective evaluation has been mainly conducted by questionnaires [7, 8]. The evaluation results from a questionnaire survey may change depending on how questions are asked to the subjects. Therefore, a method has been proposed to prepare a three-level benchmark dataset to evaluate the difficulty of generating non-photorealistic images [9], but the three-level benchmark dataset should be prepared according to the target non-photorealistic image. In some cases, visual or quantitative evaluation of the preservation of brightness and edges in non-photorealistic images has been done [10, 11]. The conventional evaluations [10, 11] examine the preservation of brightness and edges of photographic images, not the visual effects of newly generated non-photorealistic images. In other words, methods of directly evaluating non-photorealistic images from other aspects are also needed.

In this paper, we consider how to evaluate non-photorealistic images from a physiological aspect, and conduct fundamental experiments using gaze motion when looking non-photorealistic images. Once our evaluation method is established, non-photorealistic images can be evaluated directly compared to the conventional evaluations [10, 11], and there is no need to prepare a benchmark dataset according to non-photorealistic images

DOI: 10.24507/icicel.17.12.1341

compared to the conventional method [9]. In the fundamental experiments, two non-photorealistic images are placed side by side, the subject's gazes are tracked using an eye tracker, and subjects are asked to answer which non-photorealistic image looks more beautiful. Then, the relationship between gaze time and the answer to the question is examined. We use cell-like images [12] generated by changing the parameter values as non-photorealistic images. Cell-like patterns are composed of cell membrane and cell nucleus, and are automatically generated from photographic images. Cell-like images are overlaid with cell-like patterns in photographic images. 120 cell-like images generated from 6 photographic images were used for 20 subjects. By conducting the fundamental experiments, we will clarify the relationship between subject's preference and gazing time, and reveal the possibility of evaluating cell-like images by gaze analysis.

This paper is organized as follows: the second section describes the method for evaluating cell-like images using gaze analysis, the third section shows experimental results and reveals the possibility of evaluating non-photorealistic images by gaze analysis, and the conclusion of this paper is given in the fourth section.

2. **Gaze Analysis.** 6 photographic images shown in Figure 1 are prepared, and the respective photographic images are denoted as (a), (b), (c), (d), (e) and (f). 5 types of cell-like images are generated by changing the parameter values for each photographic image. Here, cell-like images are generated by changing the values of two parameters, and each parameter can adjust the size of cell membrane and cell nucleus of cell-like patterns. For example, the 5 cell-like images generated from the photographic image (a) are shown in Figure 2, and are denoted as (a-1), (a-2), (a-3), (a-4) and (a-5). The cell-like images (a-2), (b-2), (c-2), (d-2), (e-2) and (f-2) are generated with the same parameters. When 2 cell-like images on the left and right sides of the 5 cell-like images generated in each photographic image are displayed as shown in Figure 3, there are $20 = ({}_5C_2)$ combinations. Among the 20 combinations, the number of times that the cell-like image for each parameter is displayed is 8. Since there are 6 photographic images, there are $120(= 20 * 6)$ combinations and the number of times that the cell-like image for each parameter is displayed is $48(= 8 * 6)$.

Each of the 120 combinations is displayed, and the subject is asked to answer which cell-like image looks more beautiful. The eye tracker (Tobii Pro Lab) is used to track the subject's gazes. At this time, the distance between the display and the subject's eyes is

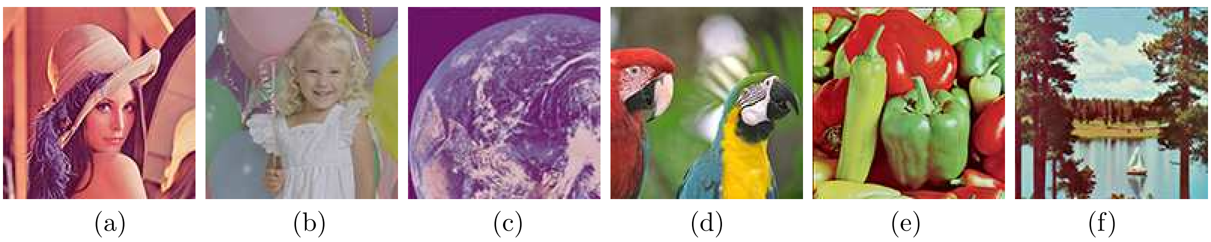


Figure 1. Photographic images

Figure 2. Cell-like images generated from the photographic image (a)

FIGURE 3. Example of displaying 2 cell-like images

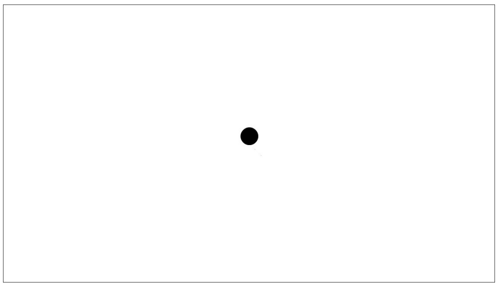


FIGURE 4. Screen with a black dot in the center on a white background

set from 55 cm to 60 cm. After displaying one combination for 7 seconds, a screen with a black dot in the center on a white background is displayed for 1.5 seconds as shown in Figure 4, during which the subject is asked to answer. The reason for displaying the screen with the black dot in the center on the white background is to move the viewpoint to the center when the combination is switched.

In the following experiments, the subjects are 20 Japanese. Among them, 10 are males and 10 are females, and 4 were 20 years old, 5 are 21 years old, 8 are 22 years old, 2 are 23 years old and 1 is 25 years old. Since there are 120 combinations, gaze analysis is performed using $2400(= 120 * 20)$ combinations. Among the 2400 combinations, the number of times that the cell-like image for each parameter is displayed is $960(= 48 * 20)$. The numbers of times that the subjects within the 960 times responded that they could look more beautiful are defined as p_i $(i = 1, 2, 3, 4, 5)$. Evaluation values a_i are obtained by the following equation.

$$a_i = \frac{p_i}{960} \tag{1}$$

In other words, a_i are the evaluation value of the cell-like image for each parameter value, and when a_i are greater than 0.5, it means that the cell-like image for that parameter value can be looked relatively beautiful. The averages of the gaze time in the 960 times displayed the cell-like images are calculated, and are denoted as t_i seconds. For reference,

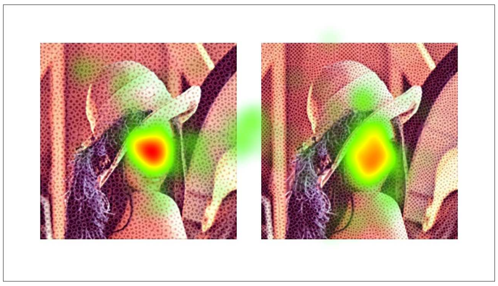


FIGURE 5. An example of a heat map

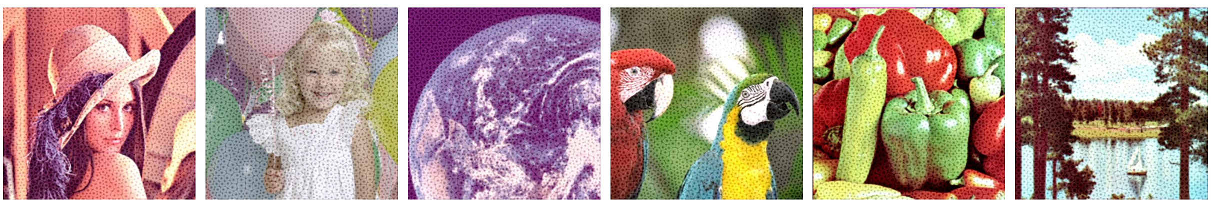
an example of a heat map that measures where and how long a subject is looking at the left and right cell-like images is shown in Figure 5. In Figure 5, the redder the color, the longer the gaze time. Using the evaluation values a_i and the averages of the gaze time t_i, the relationship between subject's preference and gaze time is revealed.

3. **Evaluation Results and Discussion.** The evaluation values a_i and the averages of the gaze time t_i using the conditions in the previous section are shown in Table 1. From Table 1, when the evaluation values a_i were arranged in descending order, a_i were 0.809, 0.631, 0.442, 0.417 and 0.201, the averages of the gaze time t_i were 3.596, 3.489, 3.095, 3.053 and 2.894, and the parameter numbers i were 2, 1, 5, 3 and 4. The parameter numbers 1 and 2 had the evaluation values of 0.5 or higher, and the parameter numbers 3, 4 and 5 had the evaluation values less than 0.5. Thus, it was found that the cell-like images with the parameter numbers 1 and 2 looked relatively beautiful.

TABLE 1. Evaluation results

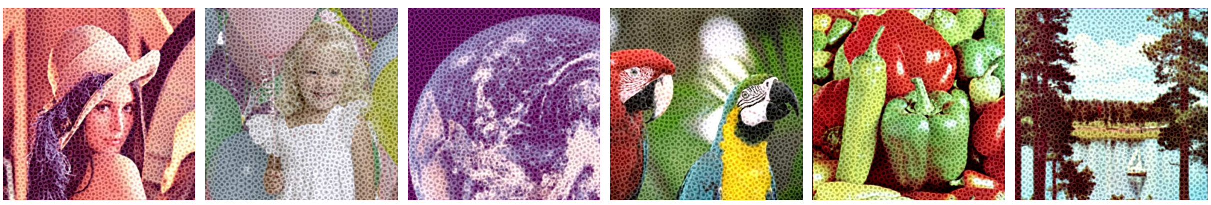
Parameter number i	Evaluation values a_i	Averages of the gaze time t_i
1	0.631	3.489
2	0.809	3.596
3	0.417	3.053
4	0.201	2.894
5	0.442	3.095

The cell-like images for parameter number 2, which had the highest evaluation value, are shown in Figure 6. The cell-like images for parameter number 4, which had the lowest evaluation value, are shown in Figure 7. From Figures 6 and 7, the cell-like images with parameter number 2 have a more linear and clearer representation of the cell membrane and a smaller representation of the cell nucleus compared to the cell-like images with parameter number 4. Since there was a large difference between the evaluation values a_2 and a_4, which were 0.809 and 0.201, respectively, it was found that the visual effects of cell-like images differed by changing the parameter values. In other words, it was found that even non-photorealistic images generated by the same method can produce



(a-2) (b-2) (c-2) (d-2) (e-2) (f-2)

FIGURE 6. Cell-like images for parameter number 2, which had the highest evaluation value



(a-4) (b-4) (c-4) (d-4) (e-4) (f-4)

FIGURE 7. Cell-like images for parameter number 4, which had the lowest evaluation value

large differences in preference for the non-photorealistic images generated by changing the parameter values.

When the evaluation values a_i were arranged in descending order, the averages of the gaze time t_i were 3.596, 3.489, 3.095, 3.053 and 2.894. Thus, the higher the evaluation values a_i, the longer the averages of the gaze time t_i. In other words, it was found that when two cell-like images were placed side by side, the subjects tended to spend more time gazing at the cell-like image that looked more beautiful.

4. **Conclusions.** We considered how to evaluate non-photorealistic images from a physiological aspect and conducted fundamental experiments using gaze motion when looking non-photorealistic images. As non-photorealistic images, cell-like images generated by changing parameter values were used. Two cell-like images were placed side by side, the subject's gazes were tracked using an eye tracker, and subjects were asked to answer which cell-like image looked more beautiful. Then, the relationship between gaze time and the answer to the question was examined. In the fundamental experiments, 120 cell-like images generated from 6 photographic images were used for 20 subjects. As a result of the fundamental experiments, it was found that when two cell-like images were placed side by side, the subjects tended to spend more time gazing at the cell-like image that looked more beautiful. Hence, we believe that there is sufficient potential to evaluate non-photorealistic images through gaze analysis.

Future studies are to compare and verify non-photorealistic images generated by different methods.

Acknowledgment. This work was supported by JSPS KAKENHI Grant Number JP23K 11727 and the Telecommunications Advancement Foundation Grant.

REFERENCES

[1] J. Lansdown and S. Schofield, Expressive rendering: A review of nonphotorealistic techniques, *IEEE Computer Graphics and Applications*, vol.15, no.3, pp.29-37, 1995.
[2] D. Martin, G. Arroyo, A. Rodriguez and T. Isenberg, A survey of digital stippling, *Computers & Graphics*, vol.67, pp.24-44, 2017.
[3] I. Ilinkin, Designing a course on non-photorealistic rendering, *Eurographics*, pp.9-16, 2020.
[4] Q. Sun, Y. Chen, W. Tao, H. Jiang, M. Zhang, K. Chen and M. Erdt, A GAN-based approach toward architectural line drawing colorization prototyping, *The Visual Computer*, vol.38, no.4, pp.1283-1300, 2022.
[5] H. Jeong, Y. Yi and D. Kim, An innovative e-commerce platform incorporating metaverse to live commerce, *International Journal of Innovative Computing, Information and Control*, vol.18, no.1, pp.221-229, 2022.
[6] D. Koschier, J. Bender, B. Solenthaler and M. Teschner, A survey on SPH methods in computer graphics, *Computer Graphics Forum*, vol.41, no.2, pp.737-760, 2022.
[7] T. Hiraoka and M. Hirota, Generation of cell-like color animation by inverse iris filter, *ICIC Express Letters*, vol.12, no.1, pp.23-28, 2018.
[8] T. Hiraoka, Generation of reaction-diffusion-pattern-like images with partially variable size, *IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences*, https://doi.org/10.1587/transfun.2022EAP1100, 2023.
[9] P. L. Rosin, Y. K. Lai, D. Mould, R. Yi, I. Berger, L. Doyle, S. Lee, C. Li, Y. J. Liu, A. Semmo, A. Shamir, M. Son and H. Winnemoller, NPRportrait 1.0: A three-level benchmark for non-photorealistic rendering of portraits, *Computational Visual Media*, vol.8, no.3, pp.445-465, 2022.
[10] T. Hiraoka, Generation of edge-preserved lint-like images using upper and lower smoothing filter and Laplacian filter, *ICIC Express Letters*, vol.15, no.12, pp.1299-1304, 2021.
[11] T. Hiraoka and J.-L. Zhang, Generation of brightness-preserving stripe-patchwork images, *ICIC Express Letters*, vol.16, no.1, pp.25-31, 2022.
[12] T. Hiraoka and K. Maeda, Generation of cell-like images using Euclidean distance from edge, *Journal of Robotics, Networking and Artificial Life*, vol.8, no.1, pp.14-17, 2021.