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EFFECTIVENESS OF AN IMAGE GENERATION METHOD THAT EXPRESSES THE VISUAL IMPRESSION OF SPACE FOR TWO-POINT PERSPECTIVE LANDSCAPES

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ABSTRACT

Photographs and CG images are generally rendered using a perspective projection. However, because a perspective projection image does not always represent the visual impression of a real space, we occasionally feel a sense of incompatibility when viewing such images. We believe that clarifying the human visual characteristics will enable the creation of more realistic images. A previous study investigated the human perception of size in a real space and proposed a magnification-rate function that shows the relationship between the subjective visual size of an object to be drawn and the observation distance. Images applying the magnification-rate function provide an impression closer to that in a real space than do perspective projection images. However, these results have only been verified for single-point landscapes. In this study, to investigate the impression of an image, we applied the magnification-rate function to images portraying landscapes with a two-point perspective. The results show that the magnification-transformed images were evaluated as being closer to the impressions in a real space than those of perspective projected images. This is similar to the evaluation of transformed images for one-point perspective landscapes, suggesting that an image transformation using the magnification-rate function is effective for two-point perspective landscapes.

Keywords: *Magnification-rate function, Two-point perspective, 3DCG, Visual impression*

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1 INTRODUCTION

With the recent spread of digital cameras and advances in 3dimensional computer graphics (3DCG) technology, there have been increasing opportunities to view photographs and videos drawn using the perspective projection method.

Perspective projection is one of the graphical methods used to represent three-dimensional objects on a plane. Since the Renaissance, many painters, including Leonardo da Vinci and Albrecht Durer, have applied the perspective projection method. Depending on the viewpoint and vanishing point, there are three types of perspective projection: one-point, two-point, and three-point perspective. One-point perspective is suitable for representations that emphasize frontality, such as a room, while two-point and three-point perspective are suitable for representations that emphasize three-dimensionality, such as a building.

Such photographs and videos are indispensable not only in movies and games but also in a wide range of fields such as education, industry, architecture, medical care, and various simulators. However, when we view a photograph, we may feel an unnatural sense in terms of the size of the object and distance.

Such unnaturalness occurs when photographs and videos are represented using the perspective projection method. With this method, the distance to the object is inversely proportional to the object size. However, the human vision system reconstructs space based on various depth clues from the images reflected on the retinas of both eyes. It is therefore known that the relationship between the distance and size perceived by a person in a real space is different from that in a perspective projection owing to such visual characteristics as the size constancy (Gibson, 1947, Smith & Gruber, 1958, Matsuda, 1970, Yasuda,1979, Watanabe, 2004).

Nagata et al. (2008a, 2008b) investigated the effect of magnification, which indicates how many times greater the size perceived in a real space is in comparison to that in a perspective projection image, and proposed the magnification-rate function (i.e., Eq. (1)) using the observation distance as a variable (Figure 1). The function is defined as follows:

$$f(D) = e^{A}$$
$$A = \frac{\alpha N_0 D^{\alpha}}{\alpha + \lambda N_0 (D^{\alpha} - 1)} - C \qquad (1)$$

where D is the observation distance, and α, λ, and C are parameters. As the experimental results indicate, when the reference distance is 4 m, these parameters are α = 0.87, λ = 0.29, and C = 1.82. The magnification rate is 1.0 at the reference distance. After creating an image by applying this function and evaluating the impression to determine how well the actual object was reproduced, it was found that the actual impression could be reproduced better than the perspective projection image.

However, this study was applied from a one-point landscape perspective. There is no knowledge that the magnification-rate function can be applied to both two- and three-point perspective landscapes. The purpose of this study is thus to apply the magnification-rate function to a two-point perspective landscape and investigate its effectiveness.

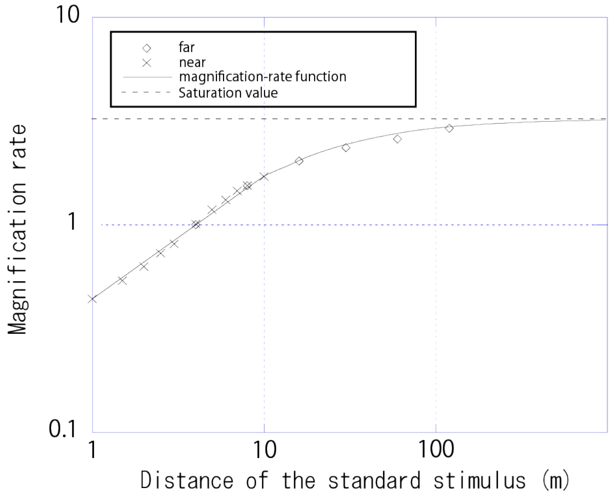


Figure 1. Magnification-rate function showing the relationship between the magnification and observation distance (Nagata et al., 2008b)

2 METHODS

2.1 Participants

Seven university students (1 female and 6 males), aged 21–24, participated in this study.

2.2 Evaluation image

The evaluation images were created using CG, and four evaluation images with different conditions were prepared. Two images (P15 and P20) were drawn with an angle of view equivalent to focal lengths of 15 and 20 mm, respectively, when considering the use of 35 mm film, and two magnification-transformed images (E15 and E20) were created (Figure 2). The algorithm developed by Mizukami et al. (2007) was used for the image transformation. All evaluation images were drawn using the rendering engine EEVEE in Blender 3.1.1 3D computer graphics software (Blender Foundation). The image was saved as a PNG file with a pixel resolution of 1524 × 1074. The parameters in the magnification-rate function were set to $\alpha = 0.87$, $\lambda = 0.29$, and $C = 1.82$. Four evaluation images were printed on glossy photo paper (PT -201A320, Canon) using an inkjet printer (PIXUS PRO-10S, Canon). The size of the printed image was 127 mm × 89 mm.


(a) f = 15 mm (perspective projection, P15) (b) f = 20 mm (perspective projection, P20)


(c) f = 15mm (converted, E15) (d) f = 20 mm (converted, E20)

Figure 2. Evaluation Images

2.3 Procedure

An experiment was conducted on a straight road adjacent to the Research Building #2 on Yamaguchi University campus.

The position of the viewpoint was the edge of the road, 12 m north and 8 m east from the corner of the building, with a height of 1.2 m (Figure 3). A chin rest was placed on the left side of the street at an angle of 25° in order to fix the direction of the face and to observe the building. The position and angle of the camera when generating the CG images were the same as the viewpoint in the real space.

The observer sat on a chair at the position as shown in Figure 3 and observed the building and evaluation image. The observer compared the evaluation image with the real space and evaluated on an 11-point scale whether the visual impression received from the image matched the visual impression when observe the real space. When the visual impression received from the image completely matched the visual impression while observing the real space, the value was set to 100%, and when it did not match at all, the value was set to 0%.

The evaluation image was presented at a position at which the height of the center of the image was 1.2 m, the presentation angle was 55° to the left from the front of the observer, and the distance from the viewpoint was 0.45 m. On the day of the experiment, the weather was either sunny or cloudy. The experiment was conducted from 12:00 to 16:00, and the season was from December to January.

The evaluated items are presented in Table 1. The locations of the evaluated targets are shown in Figure 4. The observer was instructed to observe each target without changing the face direction. The observers were prohibited from observing with their eyes narrowed, their peripheral vision, of only one eye, and from measuring the size of the object to be evaluated with their hands or tools. The evaluation images were presented in random order.

For a stable evaluation, the observers practiced in advance the same procedure as that used in the experiment. As the evaluation images used for the practice session, three images were randomly selected from those images with focal lengths of 10, 25, 35, 50, and 70 mm.

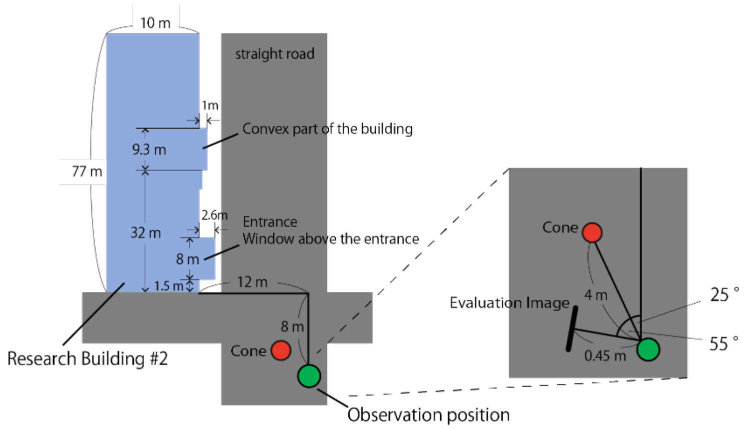


Figure 3. Observation position

Table 1. Evaluated items

Evaluated Item	Evaluated target
Distance to nearby objects	• Cone • Entrance
Size of nearby objects	• Cone (height) • Entrance (width, height) • Window above the entrance (width, height)
Distance to distant objects	• Convex part of the building
Size of distant objects	• Convex part of the building (width, height)
Angle formed by lines of the building (see Figure 4)	• Whole Building
Field of view	• Horizontal angle of view • Vertical angle of view
Comprehensive evaluation	• Whole landscape

Figure 4. Evaluated target

3 RESULTS AND DISCUSSION

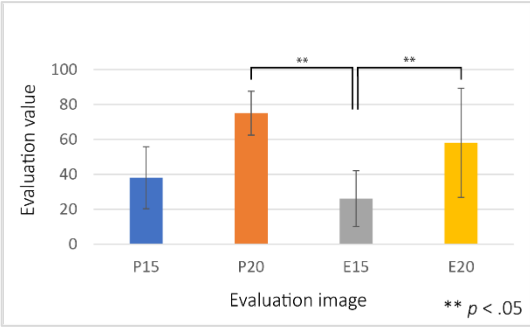
Figure 5 shows the average and standard deviation of the evaluation values of all observers. The evaluations (distance and size) of the nearby objects were the mean evaluation values of the cone, entrance, and window above the entrance. The evaluations (distance and size) of the distant object were the values evaluated for the convex part of the building. "Comprehension evaluation" indicates the evaluation value of the overall landscape impression. "Integrated evaluation" is the mean value of each evaluated item without a comprehensive evaluation.

A one-factor analysis of variance was conducted for each evaluated item using the evaluation image as a factor. Consequently, the main effect of the factor was significant at the 5% significance level. Table 2 presents the *F* and *p* values for each evaluated item. Multiple comparisons (Ryan method, significance level 5%) were conducted between each image. A combination of images with significant differences is shown in Figure 5.

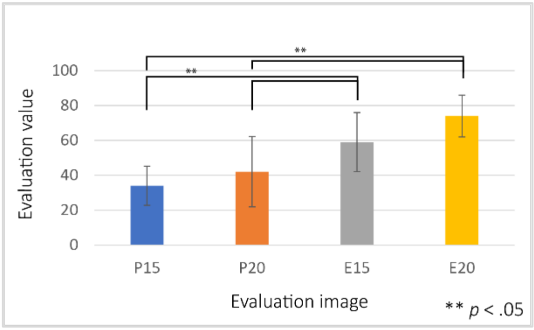
Table 2. *F*- and *p*-values for each evaluated item (see Table 1)

Evaluated item	*F* value	*p* value
Distance to nearby objects	$F(3,24) = 8.656$	$p < .001$
Size of nearby objects	$F(3,24) = 15.229$	$p < .001$
Distance to distant objects	$F(3,24) = 13.051$	$p <. 001$
Size of distant objects	$F(3,24) = 16.799$	$p < .001$
Angle formed by lines of the building	$F(3,24) = 7.094$	$p < .005$
Field of view	$F(3,24) = 3.411$	$p <. 05$
Comprehensive evaluation	$F(3,24) = 12.160$	$p < .001$
Integrated evaluation*	$F(3,24) =14.216$	$p < .001$

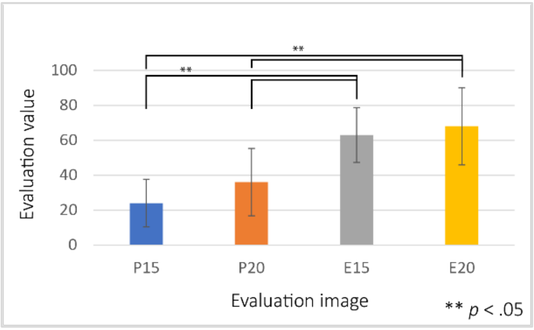
*The mean value of each evaluated item without a comprehensive evaluation.



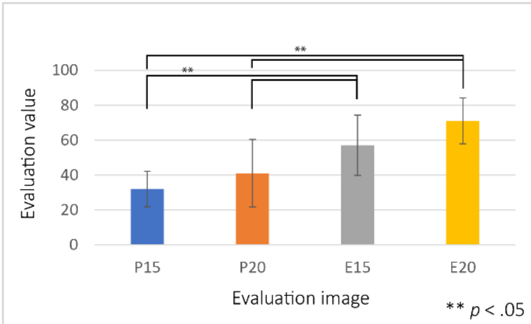
(a) Distance to nearby objects



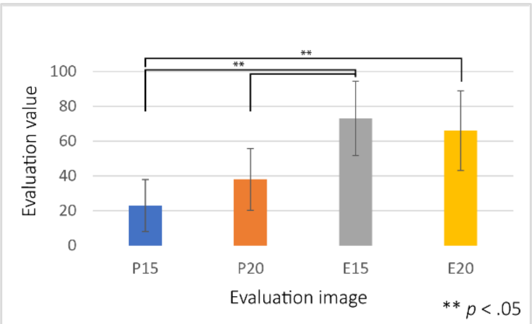
(b) Size of nearby objects



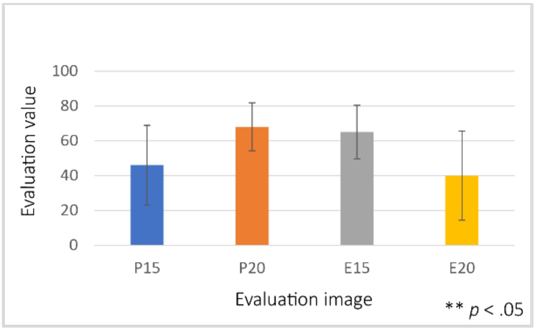
(c) Distance to distant objects



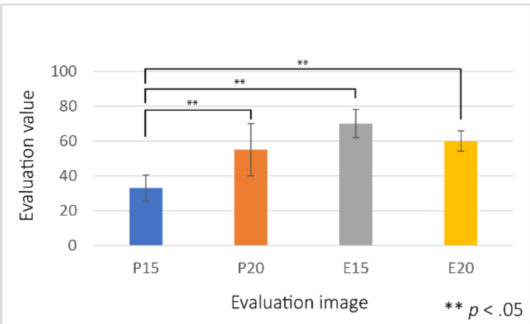
(d) Size of distant objects



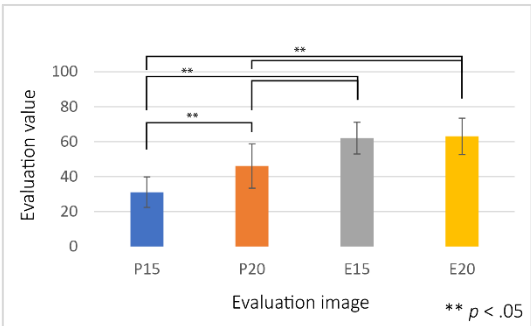
(e) Angle formed by lines of the building



(f) Field of view



(g) Comprehensive evaluation



(h) Integrated evaluation

Figure 5. Results of each evaluated item for the target image

For the “distance to nearby objects,” the evaluations of P20 and E20 were significantly higher than that of E15. If the focal length is too short, the sense of distance to nearby objects will be degraded as shown in a previous study (Nagata et al., 2008).

For the “size of nearby objects,” the evaluation of E20 was the highest and was significantly different from those of P15 and P20. Furthermore, the evaluation of E15 was significantly higher than those of P15 and P20. Therefore, it was found that the magnification-rate function was effective for the perception of size at short distances.

For the “distance to distant objects,” the evaluation of E20 was the highest and was significantly different from those of P15 and P20. Furthermore, the evaluation of E15 was significantly different from those of P15 and P20. In previous studies on single-point perspective landscapes (Nagata et al., 2008), the magnification-rate function improved the sense of distance at long lengths. This result showed that the magnification-rate function was also effective in a two-point perspective landscape.

For the “size of distant objects,” the evaluation of E20 was the highest and was significantly different from those of P15 and P20. In addition, the evaluation of E15 was significantly different from those of P15 and P20. The magnification-rate function was also effective in a two-point perspective landscape.

For the “angle formed by the lines of the building,” the evaluation of E15 was the highest and was significantly different from those of P15 and P20. The second-highest rating was for E20, which was significantly different from that of P15. In a two-point perspective landscape, the magnification-rate function improved the depiction of the angle of the building in comparison to the perspective projection image.

For the “field of view,” no significant difference between the images was confirmed through the multiple comparison procedure.

For the “comprehensive evaluation,” the evaluation of E15 was the highest, followed by those of E20 and P20. In addition, the evaluations of P20, E15, and E20 were significantly different from that of P15. For the “integrated evaluation,” the evaluation of E20 was the highest, followed by that of E15 and P20. Moreover, the evaluation of P20 was significantly different from that of P15, and the evaluations of E15 and E20 were significantly different from those of P15 and P20. Comparing the “comprehensive evaluation” and the “integrated evaluation,” both P15 and P20 showed the same tendency.

As described above, the effectiveness of the magnification-rate function in the two-point perspective landscape is shown in many of the items. By contrast, in the evaluation of the "field of view,” there was no difference from a perspective projection. In a landscape drawn from a one-point perspective, the distance to centrally located objects is often great and the objects can easily fit within the screen. In a two-point perspective landscape, the central object tends to be closer than in a one-point perspective. Therefore, in a magnification-transformed image, it is difficult to fit the central object within the image, which is responsible for the results of the "field of view."

4 CONCLUSIONS

An impression evaluation experiment was conducted by comparing a perspective projection image and a magnification-transformed image with a real space for a two-point perspective landscape. As a result, the magnification-transformed image received a high evaluation for many of the evaluated items, similar to that of the images for one-point perspective landscapes. Image transformation using the magnification-rate function is effective even in a two-point perspective landscape. In a two-point perspective landscape, a problem occurs in that the object to be drawn does not fit the screen. Since there was no difference in impression between the magnification transformed image and the perspective projection image in terms of distance to the nearby object, it is interesting to apply the magnification function to images with a higher viewpoint (e.g., 3-D CG games and animations with a third-person viewpoint) for expanding applications.

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