

Depth feeling dependence on array condition of objects

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Abstract

Depth feeling is important in image quality and expression. Depth feeling is influenced by various factors such as linear perspective, size, overlapping, shade, aerial perspective and so on. Linear perspective is known as a powerful technique for expressing depth on flat surface. But the effect of linear perspective to depth feeling is not yet understood well. In this paper, images of simple object of arrayed sphere are generated by computer graphics method and the depth feeling is subjectively estimated. It is found that the arrayed spheres on two converging lines generate depth feeling.

Introduction

Depth is important in expression of image information. Various efforts have been carried out for the expression. We feel depth from various cues such as linear perspective, size, shade, overlapping, et al [1,2]. Among them, linear perspective is important and is said to be invented in the early 1400s in Firenze, Italy [3]. Linear perspective drawing usually needs three elements such as diminishing point, horizontal line and converging lines. Linear perspective is important for depth expression in photo, painting, CG (computer graphics) and so on.

The relation between depth and linear perspective has been studied from various view point. It has been reported that linear perspective has strong effect on depth feeling, from the results that depth feeling increases as lines on load becomes noticeable [4]. Depth in picture is studied by using reverse perspective illusion [5]. It is reported that reverse perspective illusion is effective technology for understanding pictorial depth perception. The relation between Ponzo illusion and depth feeling has been studied [6,7]. It is reported that depth feeling influenced by resolution of image [8]. The reason is considered that depth feeling increased due that cues of depth becomes noticeable. Concerning simple sphere shape object, depth feeling is estimated on spheres on two lines or random. Depth is felt more when spheres are on two converging lines than when spheres are randomly distributed [9]. Understanding of depth feeling mechanism is important theme, but not yet enough. More deep understandings on generation of linear perspective is necessary.

Depth feeling induced by sphere array of simple object is estimated subjectively on various intervals between spheres. It is found that depth feeling increases as the interval between spheres decreases. By using simple objects array, relation between depth feeling and Ponzo effect is studied. It is found that Ponzo effect also occurs by ball array.

Experimental

Three groups of image for experiments are prepared. Group 1 is shown in Fig. 1. Fig. 1 (1) expresses earth and sky, and Fig. 1 (2) expresses earth and sky with two converging white lines. In Fig. 2 (1) – (6) spheres are added to Fig. 1(1). Fig. 2 (1) contains 2 spheres, Fig. 2 (2) contains 4 spheres, Fig. 2 (3) contains 6 spheres, Fig. 2 (4) contains 10 spheres, Fig. 2 (5) contains 18 spheres and Fig. 2 (6) contains 34 spheres. Spheres are arrayed on two converging lines. The cycles of spheres increase at a constant ratio from Fig. 2 (2) to (6). In Fig. 3 (a) two yellow lines added on Fig. 1 (1), Fig. 3 (b) same lines added on Fig. 1 (2) and Fig. 3 (c) same lines also added on Fig. 2 (6).

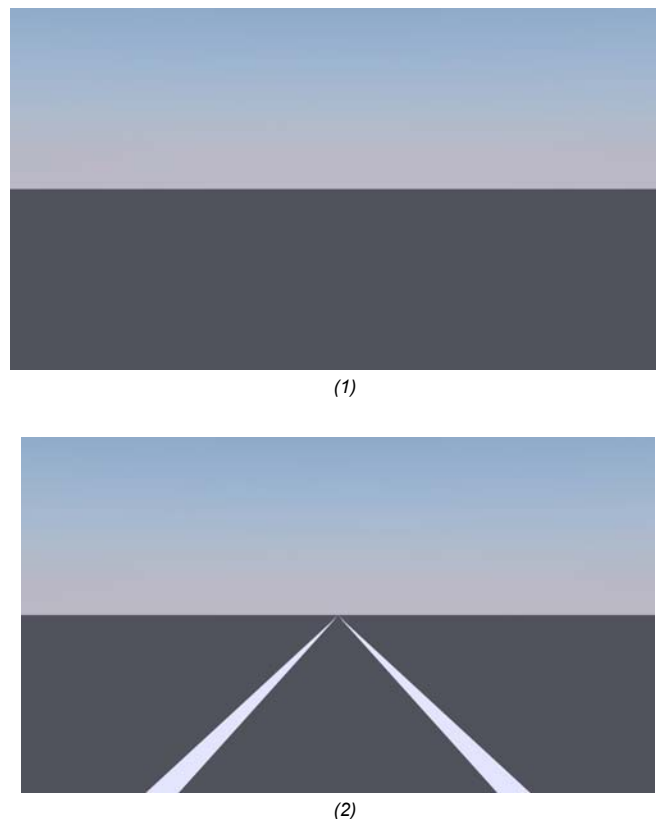


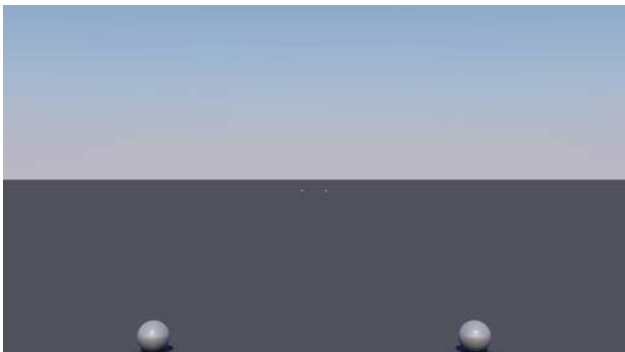
Figure 1. (1) Earth and sky, (2) earth and sky with two converging white lines.

Depth feeling is evaluated by subjective estimation on Fig. 1 (1) and (2). Concerning the scale of evaluation, level number is set 5 as, when depth is felt good, the value is 5 and when depth is not felt, the value is 1. The depth of Fig. 2 (1) to (6) are estimated subjectively with 10 levels scale as Fig. 1 (1) is 1

and Fig. 1 (2) is 10. The evaluation is carried out comparing with Fig. 1 (1) and (2). In Fig. 3 (a)-(c), length difference between upper bar and lower bar is subjectively estimated. The subjective estimation is carried out at the illumination condition of 700-900 lux on 10 students around 20 years old.



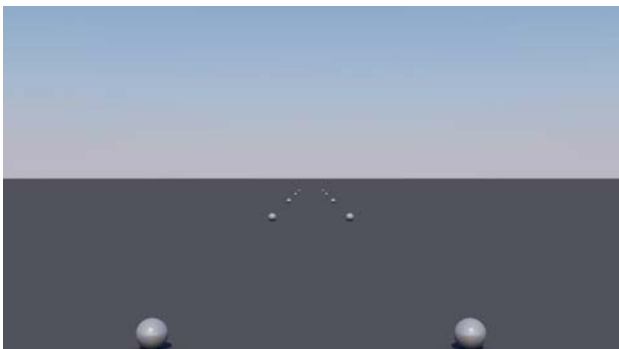
(1)



(2)



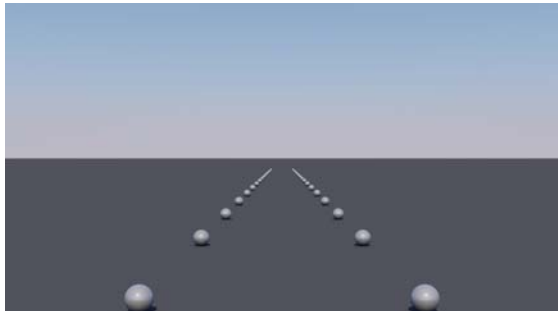
(3)



(4)

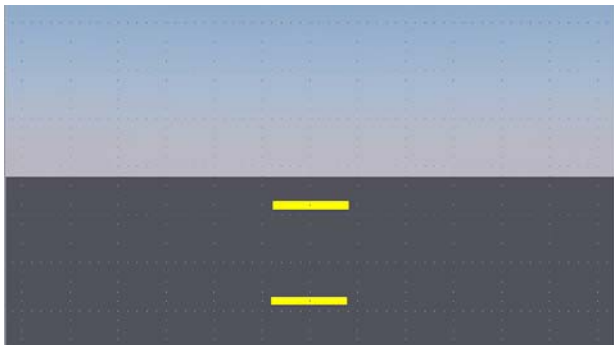


(5)

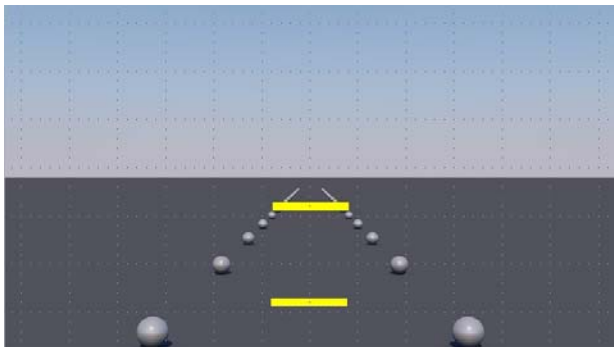


(6)

Figure 2 (1) – (6) Balls are added to Fig. 1(1). (1):2 balls, (2):4 balls, (3): 6 balls, (4): 10 balls, (5): 18 balls and (6): 34 balls. Balls are arrayed on two converging lines. The cycles of balls increase at a constant ratio from (2) to (6).



(a)



(b)

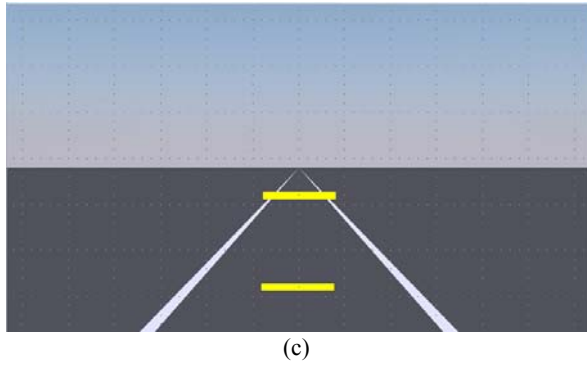


Figure 3 (a) Two yellow lines added on Fig. 1 (1), (b) same lines added on Fig. 1 (2) and (c) same lines also added on Fig. 2 (6).

Results and discussions

Subjectively estimated depth of Fig. 1 (1) and (2) is shown in Fig. 4. It is found that depth feeling is increased remarkably by adding two converging lines. It is considered that converging lines are one of important elements of linear perspective and linear perspective is strong effect on depth feeling generation. Fig. 5 shows the estimated depth feeling of Fig. 2 (1)-(6) with a scale of 10 levels as Fig. 1 (1) is 1 and Fig. 1 (2) is 10. It is found that the depth feeling increases smoothly as the number of sphere balls increases. The number of spheres has inverse relation with interval between spheres. We can guess easily spheres arranged on a line according to sphere interval decrease. Moreover sphere size decrease(or change) agrees with sphere arrangement on a line from observer view point. So we feel linear perspective well, and depth feeling is increased as the number of sphere increases.

Fig. 6 shows the subjectively estimated length of upper bar compared with lower bar on Fig. 3 (a), (b) and (c). When upper bar is felt long, the value is positive, on the other hand in inverse the value becomes negative. It is found that upper bar is felt long in three cases and upper bar is felt longest in white lines and felt middle in the spheres arranged on a line. Ponzo illusion becomes clear as depth feeling increases. It is remarked that even image of spheres arranged on a line can generate Ponzo illusion.

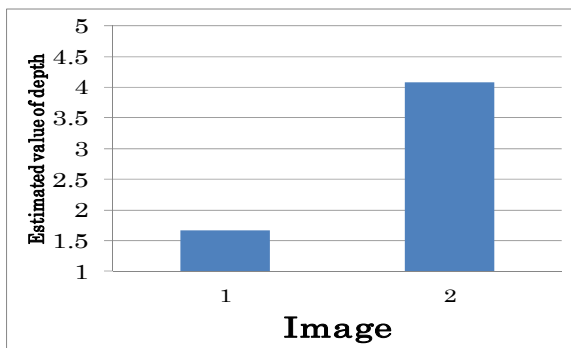


Figure 4 Subjective estimated value of depth feeling from the scale of 5 points feel depth, 4 points rather feel depth, points 3 feel depth weakly, 2 point feel depth slightly and 1 point feel no depth.

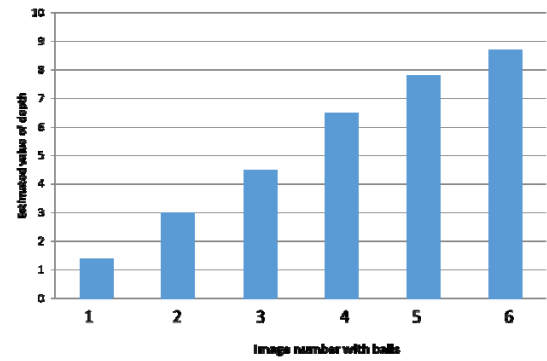


Figure 5 Subjective estimated depth feeling, estimated on the scale that the value of image Fig. 1 (1) is 0, and the value of image Fig. 1 (2) is 10.

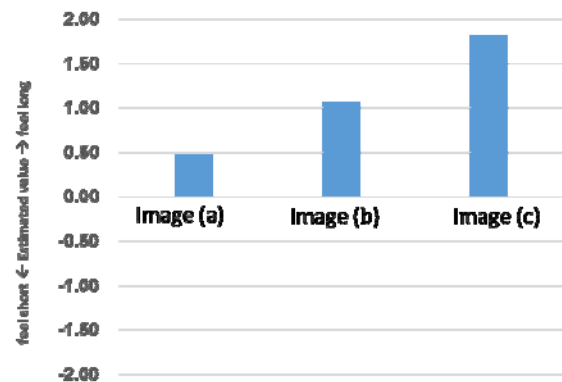


Figure 6 Subjective estimated value of length of upper bar compared with lower bar. Image (a): no lines, Image (b): balls arrayed on two lines, Image (c): two converging lines. +2 means upper bar feel long, on the other hand -2.0 means upper bar feel short.

Conclusions

Depth feeling of computer generated images of spheres arrayed on converging two lines is estimated subjectively. It is found that the depth feeling increases as the interval of the arrayed balls decreases. Ponzo effect on arrayed balls image is investigate by adding two bars on the images and its effect generation is confirmed by subjective comparison between bars on the image.

These results are effective to realize preferable expression of depth in CG, advertisement. The extraction of cues of depth feeling from photo image and depth feeling enhancement is next theme.

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Author Biography

Yasushi Hoshino (IS&T Fellow) is Professor at Tokyo Denki University. He gained Bs., Ms. and Dr. degree from the University of Tokyo, 1970, 1972, and 1984 respectively. After he gained Ms. Degree, he joined Electrical Communication Laboratories of NTT and joined the developing of first LED printer, high speed laser printer, color-laser printer by using ultra elliptical laser beam scanning, photo-induced toning technology and ion flow printing. He moved to Nippon Institute of Technology on 1994 and then has been working at Tokyo Denki University since 2013 after retirement from Nippon Institute of Technology. His recent interests are image quality estimation, image processing and electrostatic applications. He is a member of ISJ and IST.