Creating image close to visual impression formed in a real space based on apparent vanishing points and size

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We aim to propose a method to convert the liner perspective image (e.g., photograph) into an image similar to our visual impression formed in a real space. The liner perspective image has the vanishing point, on the horizon line at which parallel lines converge. In this study, we investigated apparent vanishing points formed by ceiling and walls, and formed by floor and walls in a corridor. The task of observer is putting the apparent point on a paper in binocular and monocular observation. As results of statistical test, we found that the apparent vanishing point formed by ceiling was not identical to that formed by floor, and it was above the ordinary vanishing point, in both binocular and monocular observation. Thus, we proposed a new algorithm to create an image (in terms of computer graphics) representing visual impression in the real space by the apparent vanishing point and perceived size depending on the depth of the objects.

Key words: *Photograph, Linear perspective, Vanishing point, Perceived size.*

Introduction

In watching photographs taken with a camera, we sometimes notice that the objects on the photographs are different from our impressions formed in viewing those objects in a real space in several dimensions, for example, size and distance (Gibson, 1947; Smith & Gruber, 1958; Watanabe, 2004). We aim to create an image similar to our impressions in term of understanding the relationship between the perceived geometry in a real space and the actual geometry in a photograph.

We previously proposed a method to create an image representing the perceived size in a real space (Nagata, Osa, Ichikawa, Kinoshita & Miike, 2004). The method realized that the size of each object in a perspective image drawn by the same rule as photograph was converted into the perceived size depending on the distance of the objects. This method suggests that the vanishing point in the apparent space, at which perspective lines converge, would be apart from the point derived from the method of perspective projection.

We focused on apparent vanishing point in this study. Doesschate (1956) investigated the appearance of three parallel lines at which observers looked down and reported intervals of the lines in the distance seems wider than that in the liner perspective. A point converged apparent three parallel lines were not identical to the vanishing point based on the method of perspective projection. We examined a relationship between the vanishing point based on the method of perspective projection (VP) and apparent vanishing points (AVP) in viewing a corridor from a midway of a hall in a university building. We proposed a method to create a virtual image which were similar to the appearances of the objects observed in a real space in accordance with the perceived size and apparent vanishing points.

Experiment

Methods

Apparatus. An experiment was conducted in a corridor 13.65m long, 2.48m wide, and 1.09m high (see Fig.1). The walls and floor were white. The visual angle of the end of the wall was 9.8 degrees. There was a door leading into a veranda at the end of the corridor. The observers sat on the chair, positioned in the center of the corridor. The eye level of the observer was fixed at 1.20m high by the use of a chin rest. A cross mark (the line is 15cm long) put at the end of the corridor was on the same level with observer's eye in order to keep the

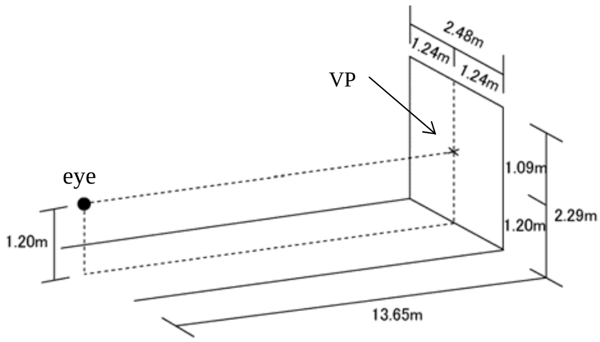

Fig.1 Apparatus of the experiment.

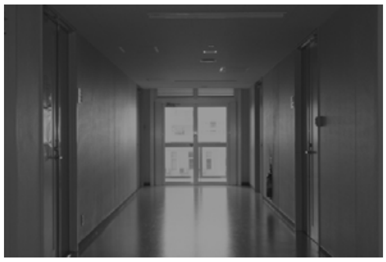

Fig.2 Photograph taken by a single-lens reflex digital camera fitted with a 35mm focal lens, the same as one taken by 35mm film camera with a 56mm focal lens. This has one vanishing point, placed at the viewer's eye level.

visual direction parallel to the floor and walls. Although this mark was identical to the vanishing point based on the method of perspective projection (VP), observers weren't told it before and during the experiment. Figure 2 was a photograph taken with camera at the same position occupied by the observers in the experiment.

Procedure. Observers imagined a crossing point of the perspective lines formed by ceiling and walls, and reported the position of the point by putting a point on a paper. In addition, they reported the same point for the perspective lines formed by the floor and walls. On the paper (148×210mm), rectangle with 8.0cm high and 8.6cm wide, the same aspect ratio as the end of the corridor, was drawn. A dotted perpendicular line was drawn along the center of the rectangle.

We prepared two viewing conditions: binocular and monocular (dominant eye) observation. The observers were instructed to keep their head facing to a wall at the end of the corridor under no restriction of eye movement during experiment. For each observer, there were 20 trials [two conditions of vanishing point (ceiling, floor) ×two viewing conditions (binocular, monocular)×five repetitions]. The order of conditions was balanced among observers. After instruction, observers carried out two trials for practice only with binocular observation.

Observers. The observers were ten college students, five males and five females, whose aged ranged from 22 to 27 years. Six observers were left eye dominant, and the others were right eye dominant. All of them had normal or corrected to normal visual acuity. While one of the observers knew purpose of our experiment, the others didn't.

Results and Discussions

We measured the difference length between the vanishing point based on the method of perspective projection (VP) and the apparent vanishing point (AVP)

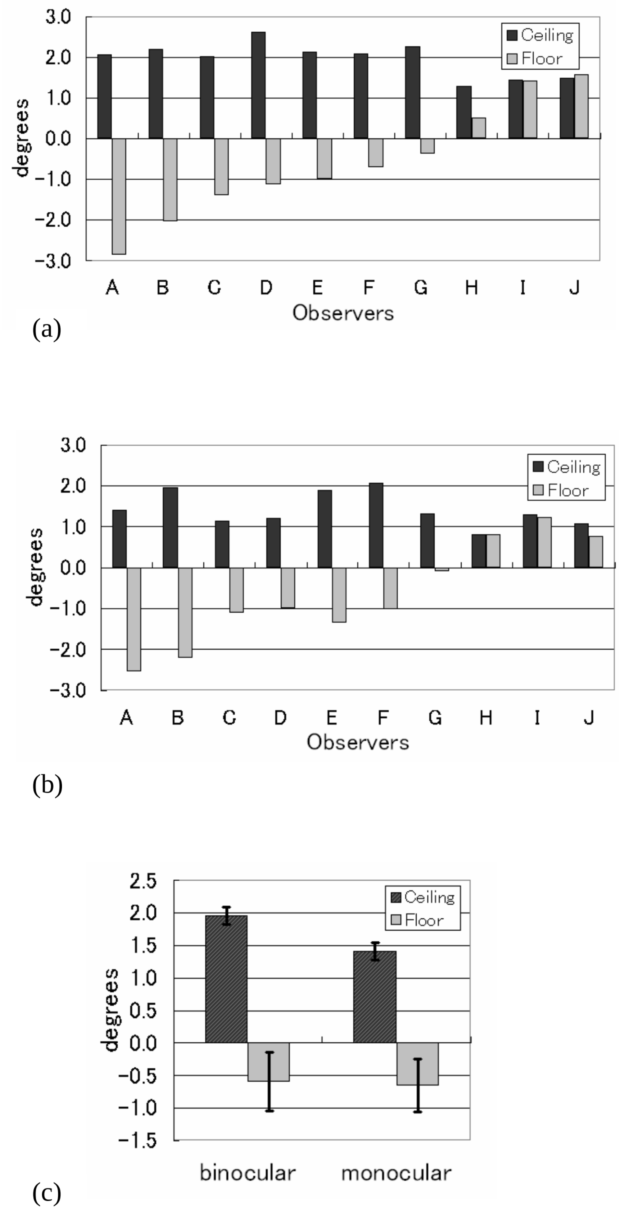

Fig.3 Differences of estimated visual angle between VP and AVP. A positive value indicates that AVP is above VP. (a)Individual mean of estimated visual angle for each observes under binocular condition, (b) under monocular condition. (c) Mean and standard error (SE) for all observers (N=10)

on the paper. After that, we calculated the visual angle of the length between VP and AVP, and we tentatively called it "difference of estimated visual angle". Figure 3 shows mean of the difference of estimated visual angle between VP and AVP, for each observer and all ones. The value of zero indicates that the location of AVP is equal to that of VP. The positive value indicates that AVP is above VP. The negative value indicates that AVP is under VP. As shown in Fig.3 ((a), (b)), AVP with ceiling was above VP in both viewing conditions of binocular and monocular. In contrast, AVP with floor was under VP for most observers, close to AVP with ceiling for a few observers.

We conducted a 2 × 2 analysis of variance for repeated measures. The factors were vanishing point condition (ceiling and floor) and viewing condition (binocular and monocular observations). The main effects of vanishing point condition [$F(1, 9)=20.2$, $p<.05$] and viewing condition [$F(1, 9)=26.7$, $p<.001$] were significant. The interaction of vanishing point condition with viewing condition was not significant [$F(1, 9)=4.55$]. These results indicate that APV with ceiling would be discrepant from that with floor, and that the difference of viewing conditions affects AVP. In addition, we conducted paired-sample t-test (one sided) to examine the difference between AVP and VP. AVPs with ceiling were significantly upper than VP in the both viewing conditions (binocular observation, [$t(9)=14.0$, $p<.001$]; monocular observation, [$t(9)=10.1$, $p<.001$]). AVPs with floor were not significant differences from VP (binocular observation, [$t(9)=1.24$]; monocular observation, [$t(9)=1.52$, $p<.01$]).

AVP with floor indicated different tendencies among observers. To identify the reason of this individual difference, we asked observers if they have knowledge about the vanishing point or the perspective, if they have experience of drawing training, and how tall their height are. However, we found that these factors are not related to the individual difference in AVP with floor.

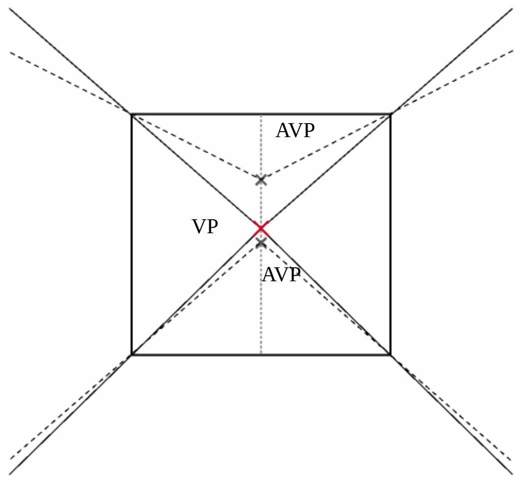

Fig.4 Explanation of VP and AVP. Solid lines indicate the perspective lines in a photograph. Dotted lines indicate apparent perspective lines estimated from our experiment.

The discrepancy between VP and AVP is related to the slope of the perspective lines formed by walls and ceiling and floor. When the lines were drawn based on AVP, angles between the lines became larger than that between the perspective lines formed the method of perspective projection (see Fig.4). This lines based on AVP is suggestive for a new image creating method to represent our visual impression in a real space.

Image Creation

In previous study, we have created an example of CG image matching to the perceived size in a real space by applying the following equation (1), which shows how the size of objects in a photograph should be magnified to match to the perceived size (Nagata, et al., 2004).

$$f(d) = \left(\frac{D}{Dc}\right)^{a} = d^{a} \tag{1}$$

where D is a viewing distance of objects and Dc is a distance located object that aren't changed its size. By the use of rating method, we confirmed that the equation (1) was effective to create an image matching to the perceived size in a real space, if we adopted approximate parameter values. A new algorithm for the image creation is explained by the following procedure. A point P (i, j) in a picture is transformed to a new point P' (i', j'):

$$i' = (i - ci)\, f(d) + ci\ , \tag{2}$$

$$j' = (j - cj)\, f(d) + cj\ , \tag{3}$$

where ci, cj are the center of the transformation and d is the distance on the point P provided by the depth information. Size of the point P' is expanded by $f(d)$ times. Any objects located at the viewing distance Dc keep the size of themselves in the image. This image processing is performed sequentially from the farthest point. Figure 5 shows an image created by applying ordinary computer graphics (CG), and Figure 6 shows depth information of the image.

We found that (ci, cj) in the above algorithm is relative to a crossing point of the perspective lines formed by walls and ceiling or floor. Figure 7 shows a newly created image based on the proposed method. Two crossing points were not identical.

General Discussion

We confirmed that AVP with ceiling was clearly above VP, however AVP with floor was close to VP. We assumed that the difference between AVP with ceiling and floor was related to the anisotropic perception of distance and size depending on visual direction and viewing distances. For example, when the viewing distance ranged from 1.0 to 1.5m, the distance is overestimated in upward direction, and underestimated in downward direction. However, when viewing distance is 10m and over, the distance is underestimated in upward direction, and overestimated in downward direction (Makishita, 1947; Morinaga, Noguchi, & Oishi, 1961). We have to consider the relationship between AVP and anisotropy in detail.

In future study, we need to examine the validly of the image creating method, and whether the magnified size of the objects locating at a distant position and apparent vanishing points bring a close impression to the perceived image in a real space or not.

Fig.5 An image created by applying ordinary computer graphics (CG) (1600×1200 pixels). Theoretically, the image is the same as a photograph taken by a camera with 35mm focal lens.

Fig.6 Depth map of the CG image. This image represents the distance map of the objects in Fig.5.

Fig.7 Newly created image by applying the proposed method when (ci, cj) = (800, 800). The size of object magnified depending on the distance of objects according to equation (1). In addition, crossing point of the perspective lines is not identical to that of the vanishing point in Fig.5.

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