

Study on correlation between linear perspective and depth feeling by subjective estimation

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Abstract

Image quality of image printing system has been improving rapidly. Depth feeling is important in image quality. Depth feeling is controlled by various factors such as linear perspective, size, overlapping, shade and density so on. Linear perspective is powerful technique for expressing depth on flat surface. Concerning the studies on depth feeling, its dependence on pixel number has been reported. But other factors influence depth feeling is not yet understood well.

Landscape image include linear perspective components is generated by computer graphics method. Changing linear perspective intensity, depth feeling is subjectively estimated. It is confirmed that linear perspective is very important in depth feeling.

Introduction

Imaging technologies have progressed and we can enjoy excellent quality images. Display technology is advancing from full high vision 2K (1920x1080pixels), moving to 4K (3840x2160pixels), and 8K (7680x4320pixels) in near future¹⁾. Image capturing technologies also become high resolution of around 8 K^{2,3)}. It becomes gradually familiar for us to watch high quality image. As a result, our demand to image quality becomes high. The image quality is influenced by various factors of resolution, color reproduction, sharpness and so on.

Depth feeling is also one of important factor in image quality. Good expression of depth feeling is important in imaging system for high quality image. We feel depth even on two dimensional image from the experience and knowledge. Concerning the resolution of the image, depth feeling has been investigated. It is reported that the depth feeling increases from 0.5 K (480x270) to 4 K (3840x2160) in printed material⁴⁾ and also in display⁵⁾. Concerning shading image, the relation between depth perception and resolution is studied in the range from 2 K to 8 K⁶⁾. It has been proposed that the cue of depth feeling is easy to be recognized as the resolution increases^{4,5)}. Linear perspective is important cue of depth feeling. However the understanding of the influence of linear perspective is not enough.

In this report, the relation between depth feeling and linear perspective is studied. Review of depth feeling cues is carried out. Two cases of image such as random arranged trees and arrayed trees are prepared with 3 level of roadway density. These depth feelings are estimated subjectively. It is found that the depth feeling increases as the linear perspective become definite.

Image for comparison between linear perspective effect and size effect is prepared. It is proposed that linear perspective has stronger influence than size effect.

Depth cues

There are many factors which make us feel depth/ or stereoscopic (three dimension) on the two dimensional plane. There are several cues as for depth feeling⁷⁻¹¹⁾. They are linear perspective, size effect, overlapping, shade, fading by light scattering, texture and so on. Linear perspective technique is powerful technique which is said to be invented by Italian painter around 15th century for generating depth feeling¹²⁾. Concerning extremely simplified images as shown in Fig. 1(1) and (2) are prepared¹³⁾, if examinee feels two converging lines as road, he feels depth.

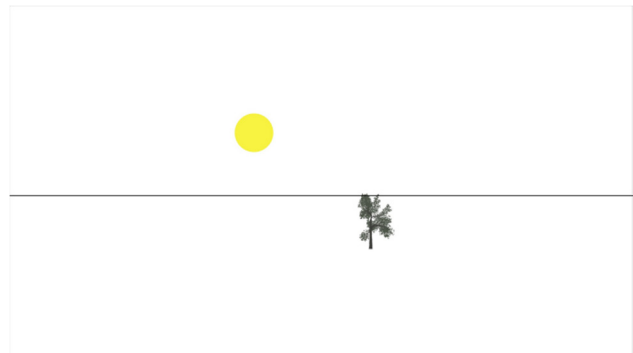


Fig. 1 (1) Simplified image of moon, tree and horizon¹³⁾.

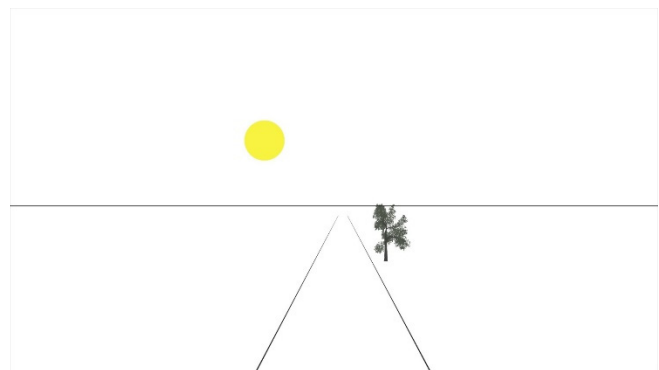


Fig.1 (2) Roadway is added to Fig. 1 (1)¹³⁾.

Concerning size effect, the size of object become small as its distance increases. The depth feeling is obtained from our experience that our perceived size decrease as distance increase. However, according to Ponzo illusion¹⁴⁾, it is considered possible interpretation that perspective-effect is more dominant than the size effect. It is guessed that linear perspective effect has strong effect on our depth feeling, so that we feel more depths as we feel more perspective.

Experimental

Two sets of image with linear perspective and trees are prepared by CG (Computer Generation) technology. One set is shown in Fig. 2 (1)-(4). Same kind trees are arranged randomly. Another set is shown in Fig. 3 (1)-(4). Same kind trees are arranged on a line like roadside trees.

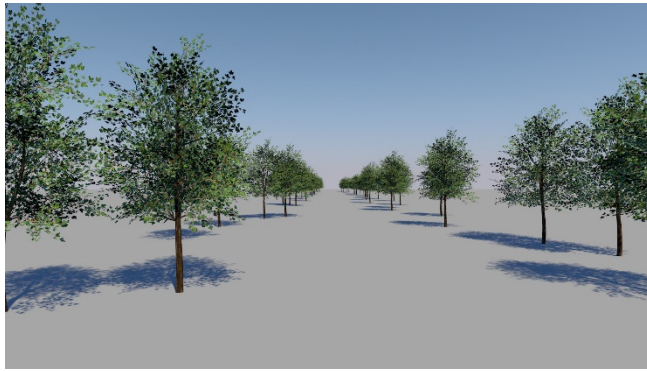


Fig. 2 (1) CG (computer generated) forest image of no roadway line. Trees are arranged randomly.



Fig. 2 (2) CG forest image of weak roadway line with center line



Fig. 2 (3) CG forest image of medium intensity roadway line with center line.



Fig. 2 (4) CG forest image of strong intensity roadway line with center line.



Fig. 3 (1) CG forest image of no roadway line. Trees are arranged on a line.



Fig. 3 (2) CG forest image of weak roadway line with center line.



Fig. 3 (3) CG forest image of medium intensity roadway line with center line.



Fig. 2 (4) CG forest image of strong intensity roadway line with center line.

In Fig. 2 and Fig. 3, three white levels of roadway edge and center markings are prepared. These images of 1920x1080 pixels were printed by inkjet printer (EPSON: PV-5V) and its size is 20x12cm² on high quality glossy paper (EPSON: Crispia).

Images of Fig. 2 and Fig. 3 (1), (2), (3) and (4) are shown to subject at the same time with the condition of florescent lamp illumination of 600-800lux. Question is as follows: evaluate the depth feeling of the images as following scale 5stages of good,

rather good, middle, rather bad, and bad. 5 stages and between the stages are possible to select, so 9 levels are possible. The subjective estimation is carried out by 20 persons.

Results and discussions

The results of subjective estimation on depth feeling of Fig. 2 and Fig. 3 are shown in Fig. 4. It is found that depth feeling increases as the roadway density become definite and also that we feel more depth when trees arrayed on a line than when trees are randomly arranged.

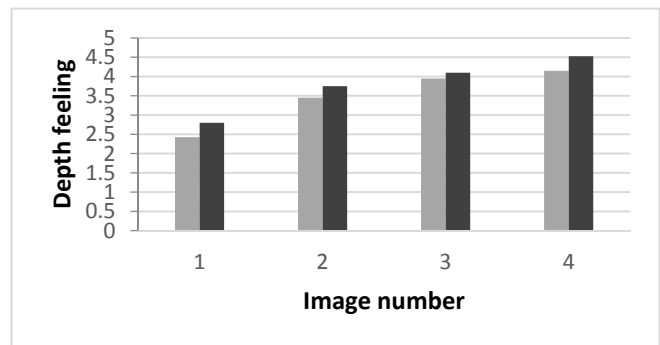


Fig. 4. Depth feeling dependence on image (1) – (4) of Fig. 2 and Fig. 3. Number means the number of Fig. 2 and Fig. 3. Left side gray bar is Fig. 2 and right side back bar is Fig. 3.

Effect of linear perspective

By using CG down town image, it has been reported that the depth feeling of down town increases as the linear perspective become definite¹³⁾. Same dependence on roadway line density is obtained in these forest images of Fig. 2 and Fig. 3. It is found that the depth feeling difference between Fig. 2 (1) and (2) is big, and also between Fig. 3 (1) and (2) is big. The difference is existence of roadway line. It is assumed that linear perspective has strong effect in depth feeling.

Comparison between random arranged trees and arrayed trees

From Fig. 4, it is found that more depth is felt on the arranged trees image of Fig. 2 (1)-(4) than randomly arranged trees image of Fig. 3 (1)-(4) in all line density cases. So it is considered that size distribution of trees is same and the difference is only trees arranged on a line or not. Characteristic points of trees such as top, bottom and center of trees are on a lines like linear perspective. It is considered that arrayed trees generate linear perspective effect.

Size effects

In Fig. 2 (1) various size of same kind of tree is arranged. Although there is no linear perspective in Fig. 2 (1), we feel depth. We feel depth even in no linear perspective image such as Fig. 2 (1). This is considered due to size effect. The effect arises from our experience that the size of object become small as its distance increases. There are small size same kind trees in the image, so we guess the small trees are in distant area. So we feel depth in Fig. 2 (1).

Competition between size effect and linear perspective

In addition to linear perspective, size effect contributes our depth feeling. Preliminary experiment is carried out. Relation between linear perspective and size effect is compared at simple case shown in Fig. 5. Same size triangles are arranged on linear perspective image. If triangle is arranged in real depth space, center triangle must be smaller. But, according to preliminary 5 persons feeling on depth, the depth feeling change is felt to be little by adding two same size triangles arrangement on the image. The central triangle size is felt bigger than right side triangle. It may be a kind of Ponzo illusion effect. So, it is proposed that linear perspective is stronger than size effect.



Fig. 5 CG down town image with two triangles on road.

Conclusions

Effect of linear perspective is investigated by using CG image. Several white levels of linear perspective are prepared and their depth feeling are subjectively estimated. It is obtained that depth feeling increases as linear perspective becomes definite and arrayed trees generates linear perspective effect.

In the case that size effect and linear perspective do not accord, it is obtained that we feel depth from linear perspective in general. It is proposed that linear perspective has stronger influence than size effect in depth feeling.

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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. (E-mail: hoshino@im.dendai.ac.jp)