Reduction of Perceived Depth Instability in Aerial Image by Using Hand or Tools to Aerial Image Position

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ABSTRACT

Hand reaching action can successfully reduce the perceived depth instability of aerial images. Moreover, hand reaching action with stick held by hand can also reduce instability. This indicates that perceived depths by only visual information and hand reaching action have different process in human brain.

1 Introduction

In recent years, aerial images are expected as a promising approach for non-contact interfaces [1]. However, as shown in Fig. 1, when aerial images are perceived only by visual information, the perceived depths tend to be unstable or frequently stuck to the nearby real objects. This is because the perceived depth of the aerial images is affected by real objects [2]. If this depth instability can be removed, aerial images can be utilized for various applications such as touchless buttons.

In the brain, the visual information received from eyes is transmitted from the visual cortex to the temporal lobe, parietal lobe, and frontal lobe. This process is dichotomized into ventral and dorsal pathways. Action like hand motion make brain select different process from only visual information [3]. For example, a previous study [4,5] about hand grasping reported that the optical illusion of perceiving the size of an object does not affect grasping behavior. This is an advantageous property for accurate touch instead of grasping even when the visual trial process for aerial image has instability. In other words, the depth instability that occurs in visual trials may be prevented by action trials.

In this paper, we clarify that the aerial image is not perceived stably by only visual information, and perceived depth becomes stable by hand reaching action.

2 Depth Perceptions by Visual Information or Hand Reaching

Figure 2 shows experimental framework to estimate the difference between the perceived depth of aerial image. In Experiment 1, we clarify the perceived depth difference between only visual information and reaching action by hand. Figure 2(a) shows visual trial in which indicator is moved to a memorized perceived depth using only visual information. Figure 2(b) shows action trial by hand reaching in which the hand is moved to the position where the aerial image can be seen.

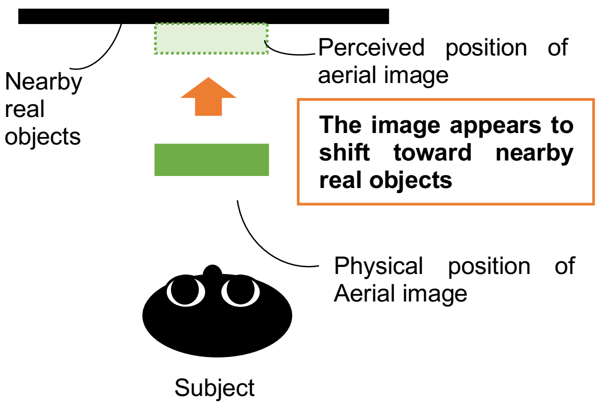

Fig. 1 Instability of depth perception for aerial images

In experiment 2, we also clarify that a holding tool is also effective to reduce the instability like the hand itself. Perceived depth difference between only visual information and reaching action by a stick is estimated. Figure 2(c) shows visual trial in which indicator is moved to a memorized perceived depth using only visual information. Figure 2(d) shows action trial by stick

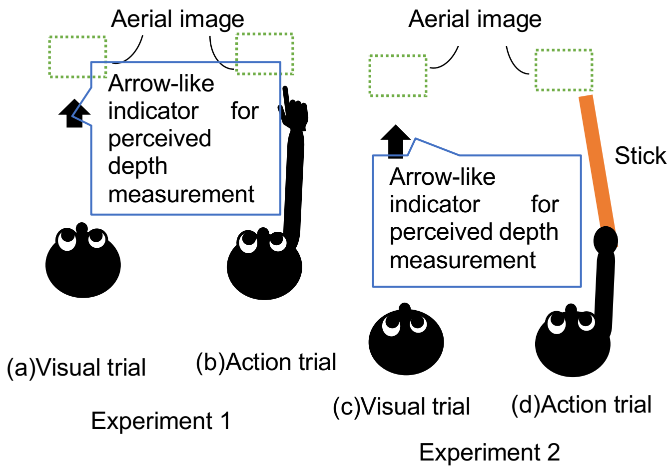

Fig. 2 Experimental framework to the estimate the difference between the position of the displayed aerial image and the subject.

reaching in which the stick held by hand is moved to the aerial image.

With holding a tool in hand, it becomes a physical and functional extension of the hand, assimilating into own body, and changing the sense of self and body image according the intention. In other words, as with accurate perceived depth in reaching action by hand, accurate perceived depth will be expected by reaching stick in our hands [6].

3 Experiment 1: Verification of Depth Perception in Reaching Action by Hand

3.1 Experimental Setup

Figure 3 shows the optics in experiment 1. An LCD and a Fresnel lens were used to form aerial image as optical real image. The size of aerial image was about 2 cm × 1.5 cm. The distance between the subject and the lens was 50 cm. The distances from the lens to the aerial image were 15, 20, and 25 cm. Black board with a rectangular opening of 15 cm × 8 cm was set in front of the Fresnel lens so that the only aerial image and the surface of the Fresnel lens were visible. The experiment was performed in a darkness room.

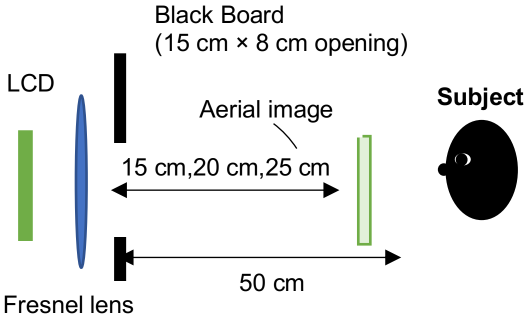

Fig. 3 Experiment 1 Methods of visual trials and action trials with hand

3.2 Experimental Time Flow

Figure 4 shows the flow of the experiment. The subjects observed the aerial image with both eyes. Upper time chat in Fig. 4 shows the time flow of visual trial. The aerial image was presented for one second and then turned off. As the arrow-shaped indicator was set to measure the distance from subject to aerial image, subject was let move the indicator to the subject's memorized perceived depth. As the aerial image disappeared before measurement of memorized perceived depth, the subject could not directly compare the depth of aerial image with the arrow-shaped indicator. The indicator was moved twice from two different directions: from the lens side to the subject side and from the subject side to the lens side.

Lower chart in Fig. 4 shows the time flow of action trial. The aerial image was disappeared before the subject's hand reached aerial image. Since the aerial image disappeared before the subject's hand reached, the

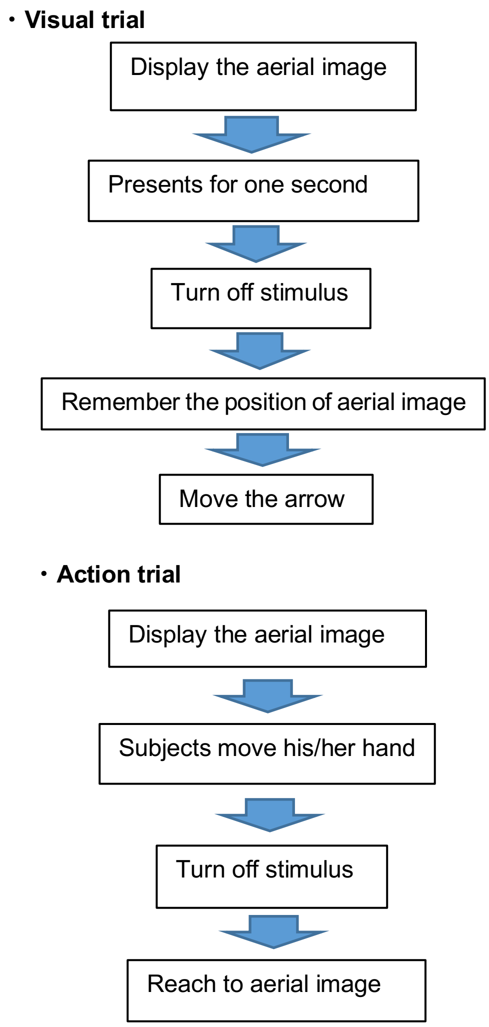

Fig. 4 Experimental flow for evaluating perceived and hand reaching positions of the aerial image

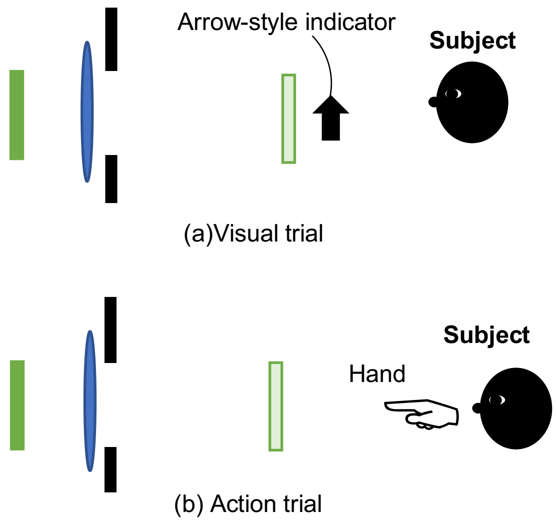

Fig. 5 Experiment 1 Methods of visual trials and action trials with hand

subject could not adjust the hand position while looking at the aerial image. The depth position of the aerial image was randomly changed at three trials (15 cm, 20 cm, 25 cm).

3.3 Experimental Results

Figure 6 shows the difference in perceived depths between the visual trial and the action trial in the experiment 1. The horizontal axis represents the position of the aerial image with the lens position as the origin. The vertical axis also represents depth perception, with the lens position as the origin. The green line represents the designed depth of aerial image.

In the visual trial, the subject perceives the image to be closer to the lens than the designed depth of aerial image. This indicates that the subject sees the aerial image as sticking to the real object of lens [7].

In contrast, perceived depth of the aerial image in the action trial is much closer to the designed depth or around the designed depth. In other words, the hand-reaching method reduce the instability of the depth perception of the aerial image.

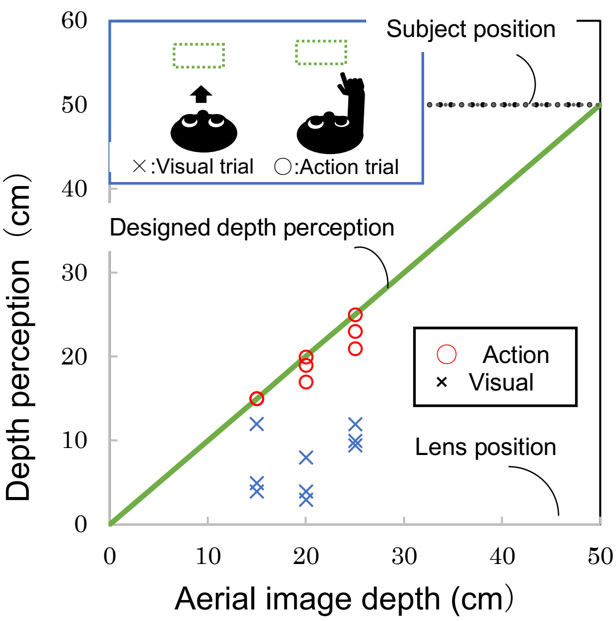

Fig. 6 Perceived and hand reaching position of the aerial image

4 Experiments 2: Verification of Depth Perception by Hand Reaching with Tool

4.1 Experimental Setup

Figure 7 shows the optics in experiment 2. The distance between the subject and the Fresnel lens was 150 cm, and the distance from the lens to the aerial image was 15 cm, 25 cm, and 35 cm. A stick was used as the simplest tool (117 cm). Black board with a rectangular opening of 15 cm × 8 cm was set in front of the Fresnel lens so that the only the aerial image and the surface of the Fresnel lens were visible. The subjects observed the aerial image with both eyes. The experiment was conducted with the room lights off.

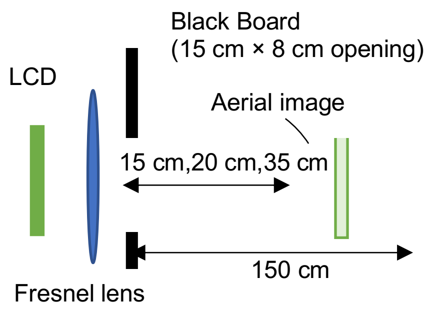

Fig. 7 Experiment 2 Methods of visual trials and action trials with hand

4.2 Experimental Time Flow

Figure 8(a) shows the experimental setup in visual trial. The aerial image was presented for one second and then turned off. The subjects observed the aerial image with both eyes. As the arrow-shaped indicator was set to measure the distance from subject to aerial image, subject was let move the indicator to the subject's memorized perceived depth. The subject was let move the indicator to the subject's memorized perceived depth. The indicator was moved twice from two different directions: from the lens side to the subject side and from the subject side to the lens side.

Figure 8(b) shows the experimental setup in action trial by a stick reaching. A stick was held in the subject's hand and the subject was let extend the tip of the stick to the perceived depth of the aerial image. The aerial image

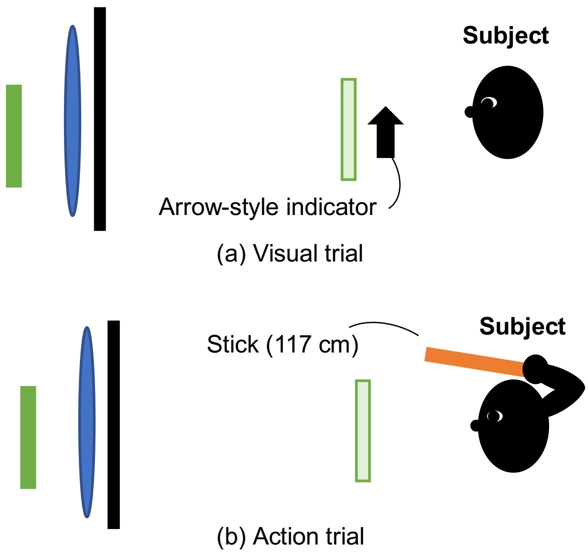

Fig. 8 Experiment 2 Methods of visual trials and action trials with tools

was turned off just before the tip of the stick reached the aerial image, and the subject indicated the depth by the tip of stick based on the memorized perceived depth.

4.3 Experimental Results

Figure 9 shows the results of the experiment 2 at distance of 150 cm from the lens. In the visual trial, the subject perceives the image to be closer to the lens than the designed perceived depth of aerial image. As the distance between the subject and the aerial image increases, the instability of depth perception of the aerial image increases.

In action trial, perceived depth of the aerial image is around or on the designed depth. In other words, the hand-reaching method reduce the instability of the depth perception of the aerial image. Therefore, even when holding a stick, the brain perceived the stick as an extension of the hand and reaching action by stick can also improve depth perception of aerial images.

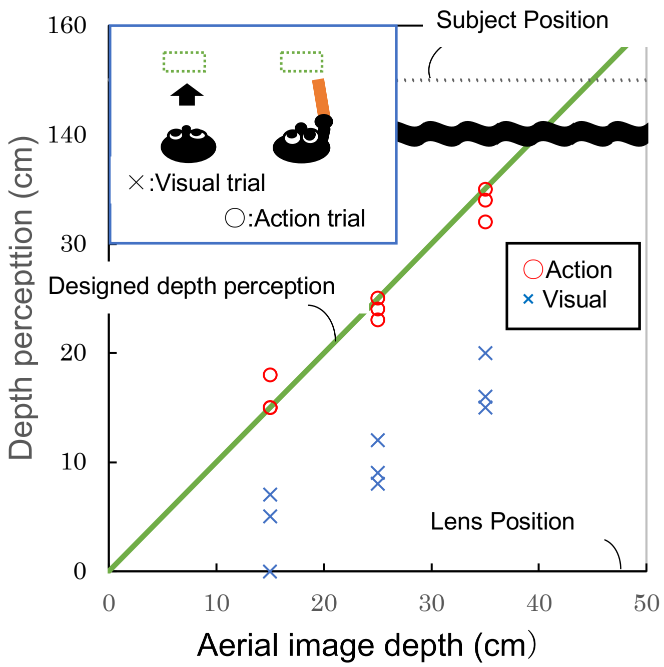

Fig. 9 Perceived and hand reaching with stick position of the aerial image

5 Conclusions

In this study, we clarified that the aerial image is perceived in the wrong position when it is perceived only by visual information. In other words, there is instability in the position of the aerial image perception when only visual information is used.

As a solution to this problem, the hand-reaching method can make better the perceived depth of the aerial image. In addition, the same can be said for tool held by hand. Depth perception of aerial image is also improved by tool held in hand. Thus, the hand reaching method can reduce the instability by only visual information in depth perception of aerial images.

We believe that our proposed hand-reaching method can provide very effective guidelines for constructing various applications using aerial images.

Acknowledgement

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