Increasing Vection Strength by Adding Random-dots in the Peripheral Visual Field

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ABSTRACT
In this paper, we demonstrated that vection strength and duration can be increased, and latency can be decreased by presenting a stimulus video on the HMD, which is added by alpha blending optical flow with random dot images on the peripheral visual field of a live-action video.

1 Introduction
In driving simulators, decrease in training effectiveness is caused by the discrepancy between the actual driving sensation and the training sensation. We attribute this phenomenon to a lack of immersion in videos and a lack of a sense of self-motion in the simulation. To solve this discrepancy, we try to induce sensation of self-motion by using vection that a stationary person perceives to be moving by visual information. This method is effective for driving simulation because drivers understand their surroundings mainly through visual information [1]. In a previous study, vection strength was measured when observing live-action video images to which processing to increase the saturation, or both were applied [2]. However, in this experiment, the vection strength was only increased to the same degree as when the live-action video (unprocessed video) was observed.

To induce stronger vection, we propose a processing method by adding optical flow of random dots in the periphery of the visual field by alpha-blending in this paper. There are two reasons for adding optical flow of random dots to the periphery of the visual field. First, displaying optical flow in the peripheral visual field can effectively induce vection [3]. Second, this is to avoid the negative effect on safety driving caused by adding additional visual information in the center of the visual field, where the driver mainly recognizes traffic condition while driving.

In this paper, we measure vection strength, duration and latency when subjects observe videos with alpha-blending processing (hereafter referred to as “added-video”) and clarify the effects of these image processing on vection strength.

2 Proposed method of video processing for increasing vection strength
First, we prepared stereo video stimuli as optical flow to be added to the live-action video. The video consisted of white dots randomly placed on a black background moving radially from the center of the image to its periphery (hereafter referred to as “random-dots video”) as shown in Figure 1. The video was generated by computer graphics and filmed by a stereo camera on virtual moving forward at 30 km/h through in quadrangular prism (6 m * 6 m * 200 m) floating 10,000 dots. When the observer viewed a dot at the center of the video, dots appeared from 10 m away and its visual angle was 1.31 degrees. We used Omega Space software [4] to generate the random-dots video.

Next, in order to add only random-dots into the live-action video, we created random-dots mask images (hereafter referred to as “mask-images”) by gray scaling and binarization (0 or 255) with a pixel value threshold of 1.

After that, we generated added-video by alpha-blending. The alpha-blending shown in equation (1), (2) was applied random-dots video and live-action video.

\[ \beta c_1 + (1 - \beta)c_2 = c_3 \quad (a = 255) \]  
\[ c_2 = c_3 \quad (a = 0) \]  

where each \( c_1, c_2 \) and \( c_3 \) are random-dots video, live-action video and added-video, \( \beta \) is constant value (hereafter referred to as “blending ratio”) and \( a \) is pixel value in mask-images. The number of horizontal and vertical pixels in the added-video are represented by \( w \) and \( h \), respectively. \( r \) is radius of the viewing angle when viewing at the unprocessed range from the observer (hereafter referred to as the “unprocessed area”). The image in the unprocessed area is represented by equation (2).

\[ \left( x - \frac{w}{2} \right)^2 + \left( y - \frac{h}{2} \right)^2 \leq \left( \frac{w}{\pi r} \right)^2 \]  

Figure 2 shows the coordinate setup of the circle \( C \) with the origin at the upper left corner of the image as defined by equation (3). The adding process takes place only outside the circle \( C \) defined by \( r \).
3 Experiment

3.1 Experimental Setup

To film the live-action video, we used the Insta360 EVO camera [5], which is capable of filming 180°-surrounding stereo video at a resolution of 3840 x 1920 pixels and a refresh rate of 50 fps and filmed it during driving forward at a speed of approximately 30 km/h. Figure 3 shows an example of the stereo live-action video filmed by this camera.

To display the stereo video, we used Vive Pro [6] HMD (Head Mounted Display) and VIVEPORT Video software [7] with the 180°-surrounding view setting of 1440 x 1600 pixels per eye (2880 x 1600 pixels for both eyes) with a refresh rate of 90 Hz.

To measure duration and latency of vection, we used a computer mouse for the subjects to hold. This allows us to measure time subject press the mouse button.

3.2 Experimental video set

To generate the stimulus video, blending ratios were set to eleven conditions $\beta = 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0$ ($\beta = 0$ is unprocessed video), and unprocessed ranges were set $\tau = \frac{\pi}{18}$. Figure 4 shows an example of stimulus video that seen by subjects wearing the HMD when blending ratio is $\beta = 1.0$ and $\tau = \frac{\pi}{18}$ (the stimulus video appears to be three-dimensional in reality).

We randomized the order in those stimulus videos and generated three sets of videos connecting them (hereafter referred to as “experimental video set”) with a one-minute break between stimulus videos. This break was designed to reduce the influence of the stimulus video observed immediately before. Each stimulus video was displayed for 10s.

3.3 Experimental Procedure

Subjects were seated and wearing the HMD. They were instructed to observe the center of the stimulus video and to press the mouse button while they perceived vection during observing the stimulus video. Duration of vection was defined as the total time that a mouse button was pressed. Latency of vection was defined as the time from starting each video stimulus to the first press of the mouse button. Subjects rated vection strength on a scale of 0 (no vection) to 100 (very strong vection) during the break between stimulus videos. This rating method was also used in previous studies [8-10]. Experimental video sets were presented three times.

Five male subjects aged 22 to 24 participated. All subjects were in good health and had normal or corrected-to-normal vision and had normal stereo vision.

3.4 Results and Discussion

Figure 5 shows the results of vection strength, when subjects viewed added-video with unprocessed areas at $\tau = \frac{\pi}{18}$. The horizontal and vertical axes indicate blending ratio and evaluated vection strength, respectively. And, the plots are marked differently for each subject, each plot is the average of three trials and standard errors are displayed. Figure 5 shows that vection strength increases when observing added-video, compared to the unprocessed video observed.

Figure 6 shows the normalized vection strength when subjects viewed added-video with unprocessed areas at $\tau = \frac{\pi}{18}$. The horizontal and vertical axes indicate blending ratio and normalized vection strength, respectively. And, the plots are marked differently for each subject, each plot is the average of three calculated value by Max-Min normalization and standard errors are displayed. As figure 6 shows, the tendency of increasing vection strength is dividing into two types. One is a type like subjects 2 and 5 (hereafter referred to as Type-A), in which the vection strength also increases as the blending ratio increases, and the other type likely subjects 1 and 4 (hereafter referred to as Type-B) has a tendency that vection strength decreases with increasing blending ratio between 0.2 and 1.

Figures 7 show the results of latency and duration, when subjects viewed added-video with unprocessed areas at $\tau = \frac{\pi}{18}$. The horizontal and vertical axes indicate blending ratio and evaluated latency or duration, respectively. And, the plots are...
marked differently for latency and duration, each plot is the average of three trials and standard errors are displayed. Figures 7 (a), (b), (c), (d) and (e) show that duration increases, and latency decreases with increasing blending ratio of added-videos, compared to the unprocessed video observed. Figure 7 (b), (d) and (e) show that latency decreases, and duration increases as the blending ratio increases.

Figure 5 shows that vection was not induced in subjects 1, 3 and 4 as observing unprocessed video. This result is contrary to the trend in previous studies [11] using stereoscopic visual stimuli. However, the unprocessed video used in this experiment may have been too weak to induce vection. This is because the video used in this experiment were captured in a driving situation on a road with few surrounding objects, resulting optical flow was not rich very much. In addition, total duration of video stimulus was relatively short (10s) compared to other studies in vection.

As figures 6 shows, in Type-A, vection strength increases greatly when blending ratio $\beta = 0.4$ or 0.5 compared to vection strength at $\alpha = 0.1$, 0.2 and 0.3. Introspective reports of Type A subjects suggest that the reason for such results may be due to the different sense of vection between a blending ratio of 0.1 to 0.3 or 0.4 and between 0.5 and 1.0. When the blending ratio is between 0.1 and 0.3 or 0.4, the background scene appears to penetrate the random-dots due to the low blending ratio, and the random-dots are observed as if they are fused into the background scene of the live-action video, and the motion of background scene enhanced by the optical flow due to the random-dots is perceived as dominant for inducing vection. However, when the blending ratio is between 0.5 and 1, the random-dots are prominent and do not merge with the live-action image and are observed as if they are floating on the live-action video space, and the motion of highlighted random-dots in the stimulus video may be perceived as dominant for inducing vection.

4 Conclusion

In this study, we measured vection strength, duration, and latency when observing videos in which random-dots video as optical flow were added by alpha-blending with live-action video in the peripheral visual field. Also, we clarified under which processing conditions vection strength increased.
The experimental results showed that vection strength and duration increase, and latency decreases when observing added-videos, compared to the unprocessed video observed.

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References