Eye direction control and reduction of discomfort by vection in HMD viewing of panoramic images

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Abstract

We have previously proposed an "eye direction exaggeration method." That facilitates rearward visibility by exaggerating the angle of the eye direction when viewing panoramic images with an HMD in a seated position. In this study, we improved this exaggeration method. However, the exaggeration sometimes increased discomfort such as VR sickness. We also tried to reduce discomfort by presenting horizontally moving particles and inducing vection stably.

Index Terms: Human-centered computing—Interaction design—Empirical studies in interaction design

1 Introduction

Most VR services that allow users to view 360-degree images are used in a seated position. However, it is difficult for users to look rearward while rotating the necks and hips in a seated position [2]. In fact, it is clear that the viewer's gaze is directed to a 90-degree range centered on the frontal direction of the video for 75% of the 360-degree video playback time on Youtube [5]. Sitting in a swivel chair makes it easier to look rearward, but the user's body motion is amplified by the rotation of the seat surface and the sensation is greatly displaced, when viewing a 360-degree image with an HMD [1]. Then, we have previously proposed an "eye direction exaggeration method," that facilitates rearward visibility in viewing panoramic images with an HMD in a seated position [3]. The direction in which the user looks is called the eye direction. By presenting a rearward view on the HMD that is different from the actual viewing direction, the user can have a rearward view without having to sit up. This method is intended for use in a posture in which the user cannot easily see rearward, and does not take into account the fact that the eye direction may go around horizontally. However, it is possible to go around the eye direction by changing posture or by sitting in a swivel chair. In this study, we propose a new exaggeration method that can cope with the case where the viewer's eye direction goes around a circle. We also propose a method to reduce discomfort by intentionally inducing vection, which means the sensation of illusory self-motion [4], by displaying horizontally moving particles in the HMD during exaggerated the angle of eye direction.

2 Eye Direction Exaggeration Method

The direction in which the viewer is actually looking, regardless of the scenery displayed on the HMD, is called the "real eye direction" and the direction of the scenery displayed on the HMD by the program is called the "virtual eye direction." The virtual eye direction is basically the same as the real eye direction, but the angle of the real eye direction is exaggerated to display the scenery on the HMD in a virtual eye direction different from the real eye direction (Figure 1-(a)). This angle at which the virtual eye direction differs from the real eye direction is called the "change point." Assuming that the angle in the real eye direction is r degrees ($-90 \leq r \leq 90$), the angle in the virtual eye direction is v degrees ($-180 \leq v \leq 180$), and the angle of the change point is a degree ($0 \leq a \leq 90$), then consider the following equation (Figure 1-(b)). The derivation process is omitted for reasons of space limitation.

$$\begin{cases} v = h(r) = e(r) = r \quad (|r| \leq a) \\ v = h(r) = f(r) = r \pm b|r-a|^c \quad (|r| > a) \end{cases} \tag{1}$$

Parameter b is "amount of change" and is determined so that $v = 180$ when $r = 90$. Parameter c ($c \subseteq N$) is "variation type." The addition and subtraction signs in the Equation (1) are calculated as addition for right-handed rotation and subtraction for left-handed rotation. We prepared some exaggeration patterns by changing parameter c and a ("Exag(c, a)," Figure 2). In the experiment, the most satisfactory pattern was the Exag(1,0) for 12 different exaggeration patterns (3 patterns for parameter c and 4 patterns for parameter a).

3 Sigmoidal Exaggeration

The eye direction exaggeration method described in the previous section assumes a seated position at home and does not expect the eye direction to circle horizontally. We try a new type of exaggeration using a sigmoidal function whose slope is close to a straight line near the front and whose slope becomes smaller near the back. In this exaggeration, assuming that the angle in the real eye direction is r degrees, consider the angle in the virtual eye direction $v = h(r)$ degrees as follows.

$$v = h(r) = \frac{360}{1 + e^{gr}} - 180 \tag{2}$$

The gain g is set, for example, so that the slope of $h(r)$ near the origin is equal to the slope of Exag(1,0) as $g = 0.025$ (Figure 3). In a simple experiment, we confirmed that the angles of the virtual eye direction were almost smoothly connected when the angle of the real eye direction is $r = \pm 180$. On the other hand, it was also found that, compared to the exaggeration method described in the

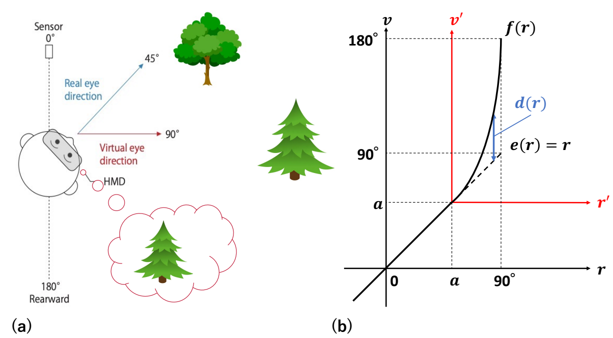

Figure 1: (a) Real and virtual eye direction of this system, (b) Conceptual diagram

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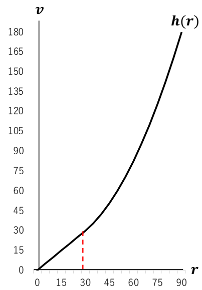

Figure 2: Example of exaggerated pattern: Exag(2,30)

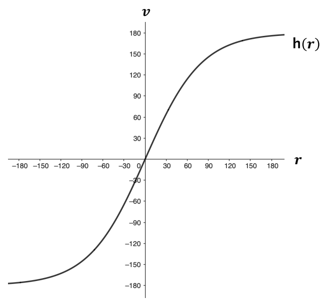

Figure 3: Sigmoidal exaggeration

Table 1: Discomfort with or without particles

background	(a) slow			(b) fast		
particles	none	equal	fast	none	equal	slow
average point	4.3	3.3	3.6	3.6	3.3	3.9

previous section, the subjects felt stronger discomfort. In the case of sigmoidal exaggeration, the change of the angle in the virtual eye direction relative to the change of the angle in the real eye direction becomes very small at around $|r| > 150$. In other words, the scenery in the HMD hardly changes in spite of the neck movement.

4 Discomfort Reduction Through Vection

Particles are displayed with white opaque and translucent tails moving in a horizontal circle around the subject in the HMD, in order to induce vection to properly perceive changes the real eye direction. To avoid disturbing the viewing of the contents, parameters of particles are set as follows (the angular velocity in the real eye direction is ω, and the angular velocity of the landscape in the HMD is $-\omega$, or $-h'(r)\omega$ when exaggerated).

1. Right or left gyration in the region where the elevation (depression) angle is $\theta_1 \leq |\theta| \leq \theta_2$ in the HMD coordinate system
2. Movement with an angular velocity equivalent to $-\omega/h'(r)^{\varepsilon}$ (ε is a constant) in the HMD coordinate system
3. 10 cm diameter for a distance of about 5.5 m
4. The number of β objects around the subject (The horizontal field of view of the HMD is approximately 90 degrees, and approximately $\beta/4$ exist in the field of view.)
5. With transparency α, the tail of the trajectory for δ seconds

5 Experiment and Conclusion

An experiment was to investigate whether the presence or absence of particles and their apparent velocity (parameter ε) contribute to the reduction of discomfort, i.e., the angular velocity in the virtual eye direction is (a) smaller: $b' = 1/3$, and (b) larger: $b' = 3$ than the real eye direction for the virtual eye direction $v = b'r$ with real eye direction r. The constant ε was investigated for two cases: the particle motion is equal ($\varepsilon = 0$), and opposite ($\varepsilon = 1$) to the change in the virtual eye direction. The subjects were asked to experience without particles, with particles (equal magnification), and with particles (slow or fast inversion). They looked around freely and rate their discomfort from 0 to 9 (Figure 4). The particles are empirically set to $\alpha = 0.005$, $\beta = 100$, $\delta = 0.15$, and are displayed in the area of $25 \leq \theta \leq 45$ degrees with the peripheral vision (Figure 5).

Figure 4: Scene of the experiment

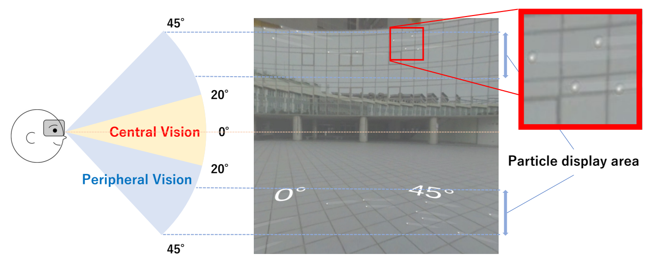

Figure 5: Viewing area and particle display (ω =3.7 $[rad/s]$, $-\omega/h'(r)^{\varepsilon} = -3.7$ $[rad/s]$)

When the angular velocity of the virtual eye direction is much smaller than that of the real eye direction, the presentation of particles with the angular velocity of the real eye direction, i.e., the same level as that of the real neck rotation, was found to be effective in reducing the discomfort (Table 1).

In another experiment as the sigmoidal exaggeration with $\varepsilon = 0$, the subjects were asked to look around freely, especially by intentionally lifting their hips, and to circle around beyond the back. Easy rearward visibility and a rotational motion with little discomfort were confirmed. As a future work, we would like to examine the parameters of the particles and consider dynamic modification.

Acknowledgments

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