Easy rearward visibility by the control of eye direction in viewing panoramic images with HMD

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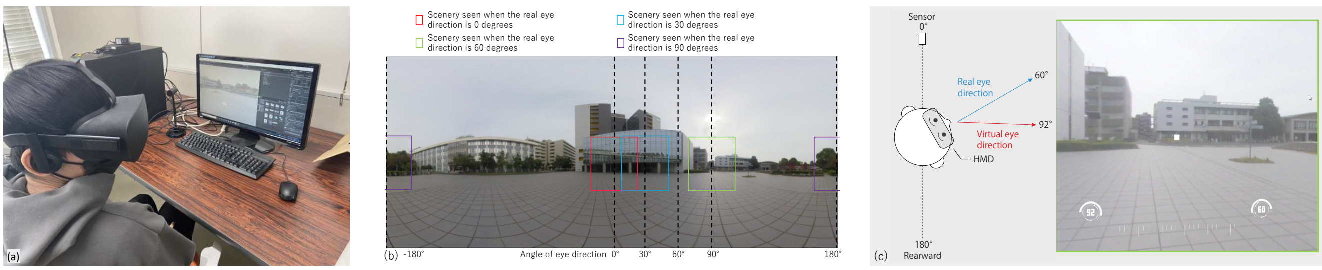

Figure 1: (a) Appearance of experiment, (b) Example of panoramic 360-degree image used in the experiment, (c) Schematic diagram when the angle in the real eye direction is 60-degree

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

KEYWORDS

HMD panoramic view, eye direction control, rearward visibility

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1 INTRODUCTION

The development of home-use HMDs has made it possible for many people to enjoy VR in the comfort of their own homes. 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 [K.Yonemoto and T.Kondo 1995]. Sitting in a swivel chair makes it easier to look rearward, but it has been reported that when viewing 360-degree images with an HMD, the rotation of the seat surface amplifies the user's body movements, resulting in a larger sensory discrepancy [Y.Banchi and T.Kawai 2018]. In this paper, we propose a new method that enables rearward viewing while sitting in a chair. 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 (Figure 1). We also examine better way to display how much differently rearward is displayed on various parameters.

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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 2). 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 3).

$$\begin{cases} v = e(r) & (|r| \leq a) \\ v = f(r) & (|r| > a) \end{cases} \tag{1}$$

Here $e(r)$ and $f(r)$ are functions of r. Now, noting that $r \geq 0$, $v \geq 0$, and considering the new coordinate axes r' and v', $e'(r')$ and $f'(r')$ can be defined as follows. And substitute Equation (2) into Equation (1) to determine $e(r)$ and $f(r)$, as Equation (3).

$$\begin{cases} v' = e(r' + a) - a = e'(r') \\ v' = f(r' + a) - a = f'(r') \end{cases} \tag{2}$$

$$\begin{cases} e'(r - a) + a = e(r) \\ f'(r - a) + a = f(r) \end{cases} \tag{3}$$

Considering $d(r)$ that is the difference between $e(r)$ and $f(r)$ ($r \geq 0$), $d'(r')$ can be defined as folows,

$$\begin{gathered} d(r) = f(r) - e(r) \\ f(r) = d(r) + e(r) \end{gathered} \tag{4}$$

$$\begin{aligned} d'(r') &= f'(r') - e'(r') = f(r' + a) - e(r' + a) = f(r) - e(r) \\ &= d(r) \end{aligned} \tag{5}$$

Here, noting that the change point is the origin, we consider difference between real eye direction and virtual eye direction as follows,

$$d'(r') = br'^{c} \quad (c \subseteq N) \tag{6}$$

Parameter c ($c \subseteq N$) is called "variation type" and the slope of the tangent line to $d'(r')$ at $r' = 0$ is zero, except when $c = 1$. So we obtain Equation (7) and consider again Equation (1) as Equation (8).

$$\begin{aligned} v &= f(r) = e(r) + d(r) = e(r) + d'(r - a) \\ &= e(r) + b \cdot (r - a)^{c} \end{aligned} \tag{7}$$

$$\begin{cases} v = e(r) = r \quad (|r| \leq a) \\ v = f(r) = r \pm b|r - a|^{c} \quad (|r| > a) \end{cases} \tag{8}$$

The addition and subtraction signs in the Equation (8) are calculated as addition for right-handed rotation and subtraction for left-handed rotation. We change parameter c and a like Figure 4, and call "Exag(c,a)." The numbers in parentheses indicate the variation type on the right and the angle of the change point on the left. For example, the virtual eye direction is the real eye direction the same as up to 30 degrees, and it is exaggerated quadratically from 30 degrees in Exag(2,30).

3 EXPERIMENTS

Two experiments were conducted. In the first experiment, we tested for problems with exaggeration and explored the most appropriate exaggeration. Twelve different exaggeration patterns (3 types of parameter c and 4 types of parameter a) were prepared for the experiment. Subjects were asked to use the HMD to randomly try new methods in all exaggeration patterns and to answer a questionnaire. The questionnaire asked about "usability" of use and "discomfort." We defined "satisfaction" as the score for usability of use minus the score for discomfort, and used this score to determine the superiority of the exaggerated patterns. This relationship was obtained from preliminary experiments. The results are shown in Figure 5, which shows that among the 12 exaggeration patterns, Exag(1,0) has the highest score of satisfaction, and the larger the angle of the change point, the lower the degree of satisfaction. It is confirmed that low-order, near-linear exaggeration is preferred.

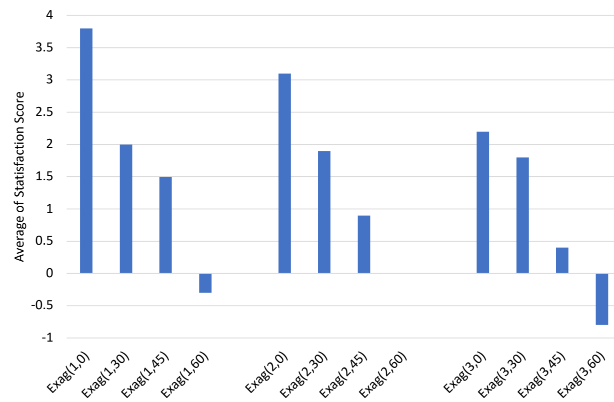

Figure 5: Result for appropriate exaggeration

The second experiment examined the usefulness of the proposed exaggeration method. Subjects responded with an image of the usefulness of our method that more closely resembled actual use. Subjects tried two display ways, assuming that they would enjoy panoramic 360-degree image of foreign tourist destination. One was the most satisfactory Exag(1,0) in the first experiment; the order was the normal condition (no exaggeration). As a result, four out of four subjects responded that it was difficult to see rearward in the normal condition, but that exaggeration made it easier to see rearward.

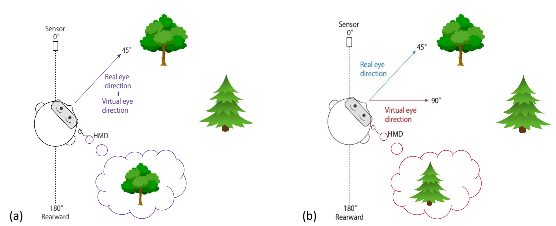

Figure 2: (a) Normal real and virtual eye direction, (b) Real and virtual eye direction of this system

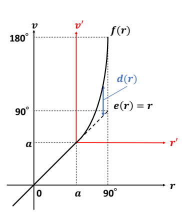

Figure 3: Conceptual Diagram

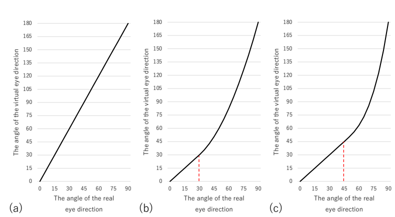

Figure 4: Example of exaggerated pattern: (a) Exag(1,0), (b) Exag(2,30), (c) Exag(3,45)

4 COUCLUSION

We proposed a new method that enables rearward visibility while sitting in a chair and conducted two experiments to see if there were any problems with exaggeration. As a result, it was confirmed that this method facilitates rearward visibility and allows easy enjoyment of scenery in all directions. As a future work, we would like to further suppress VR sickness and find a better exaggeration method that is closer to the actual VR use.

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