Reverse 3D Sound Flow Can Decrease VR Sickness?

Category: Research

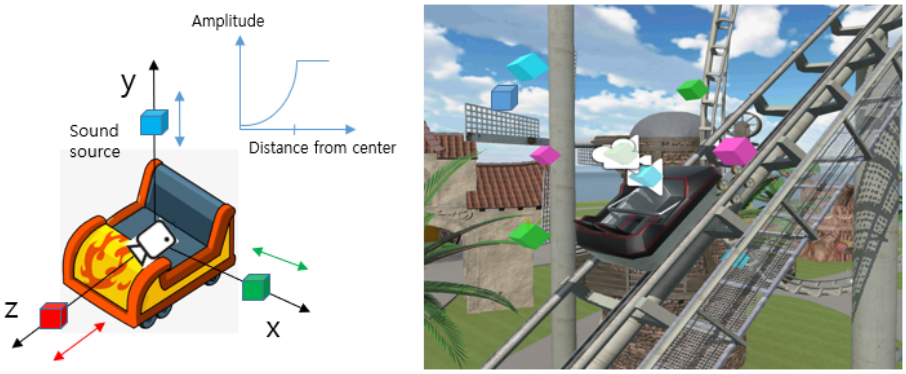

Figure 1: Reverse 3D sound flow: Three sound souces are placed with respect to the user/cart in the VR roller coaster space. Their positions and distance from the cart center is adjusted according to the motion profile of the cart. The faster it goes, the farther the sound sources is adjusted and their volume characteristics are changed such that the farther they are the louder they become (to a limit) and vice versa.

Abstract

One way to battle simulation sickness in virtual reality is to reduce the visual feedback of the apparent motion. In this vein, mixing in and overlaying motion trail in the reverse direction to the original motion in the virtual contents have been suggested as one such method. However, as such visual feedback can be intrusive and distractive to the original, its application must be restrained. In this poster, we consider supplementing the sickness reduction methods based on visual manipulation of the content with 3D sound effects that mimic the behavior of reverse motion flow. For instance, in a forward motion, the environment sound sources should be normally heard louder as one approaches them - here, we emulate the reverse, in hopes of eliciting and strengthening the vection nullifying effect. The pilot experiment tested of the lone effect of such "reverse" sound effect (or airflow) against the conditions of no sound or natural sound effects and revealed the positive results, indicating the potential when combined with the visual oriented approaches.

Keywords: Virtual reality, reverse sound flow, motion sickness.

Index Terms: Human computer interaction (HCI)—Interaction paradigms—Virtual reality;

1 Introduction

One way to battle simulation sickness in virtual reality (VR) is modulate the amount of visual feedback that conveys the extent of the perception of apparent motion, known as vection. This is based on the theory of sensory mismatch of stimulations between the visual (of apparent motion) and vestibular (stationary body) channels [5]. Few such approaches like the dynamic field of view (FOV) adjustment [3], image blurring during rotation [1], using rest frames such as the virtual nose, [8] and adding reverse optical flow [6] have been suggested. However, concerns exist whether such methods could be content intrusive and distractive affecting the sense of presence, immersion and user experience. For example, the virtual nose or the black blank peripheral region by the FOV adjustment occupy significant portion of the content screen space.

In this poster, we consider supplementing the sickness reduction methods based on such visual manipulation of the content with 3D sound effects. In particular, we propose to strengthen the elicitation of the sense of the reverse flow through the aural channel. For instance, in forward motion, the environment sound sources should be normally heard louder as one approaches them - here, we emulate the reverse. One question however is whether such an aural effect would stimulate or affect the vestibular organ, creating a rather confusing situation. That is, the vestibular organ would receive mixed signals - stationary bodily but moving aurally. We conduct a pilot testing of the lone (not supplementary) effect of such "reverse" sound effect against the conditions of no sound or natural sound effects.

2 Related Work

VR (or simulation) sickness brings about unpleasant symptoms such as disorientation, headache, and nausea when using immersive VR simulators, especially with navigation contents [5]. VR sickness is explained mostly by the aforementioned sensory mismatch theory [5]. Approaches to mitigate the VR sickness through visual manipulation have been shown to be quite effective [3], [1], [8] [6]. Other research have reported that multimodal stimulations, e.g. visual added with sound, vibrotactile, or airflow stimulations can further help lower the extent of VR sickness (but not by them alone) [2], [7].

3 Reverse 3D Sound Flow

The reverse 3D sound flow was created in the following way. We illustrate the method using the case of virtual roller coaster, which served as the experimental test content in this work. First, the sound source of airflow passing by the one's ears was chosen. Normally, such an airflow (imagining it as a small sound source) would sound soft at first, the louder as one moves forward, the loudest when passing by the ears, then become softer. When rotating, a similar principle can be applied - e.g. as one rotates to the right, the airflow source would approach from the right, gradually increasing in its volume, become loudest when passing by the ears and then become softer. This logic is all reversed in our implementation of the reverse 3D sound flow.

Three sound sources are positioned with respect to the user position (e.g. the roller coaster cart), as shown in Figure 1, along the three principal axis. The positions of these sound sources are effectively attached to the user (who is attached to the roller coaster cart) but unaffected by the user's view rotation. The core idea is to dynamically adjust the positions of the sound sources along the axes based on the

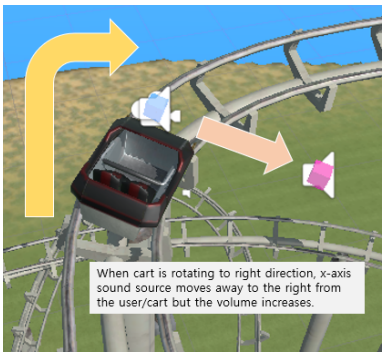

Figure 2: A snapshot of the roller coaster cart and the positions of the sound sources as the cart veers to the right.

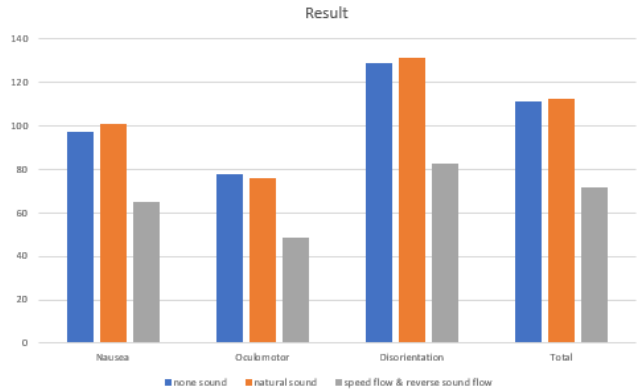

Figure 3: Comparison of the after sickness levels (SSQ) among the test conditions: (1) No sound, (2) Natural 3D sound, (3) Reverse 3D sound flow. Despite no statistically significant differences, the general trend is conditions (1) and (2) are quite at the similar level, while the (3) has marked lower sickness level in all categories and the total.

movement profile of the user/cart. The sound sources can only move within a fixed distance (pre-determined by trial and error) to and fro with respect to the user/cart position. Normally, when the sound source is at the farthest distance from the user, it would sound the softest. Here, such logic is reversed by editing the sound amplitude characteristics through the functionality of Unity with which this VR content is authored. This sound amplitude function is modeled as a simple quadratic equation parameterized by the distance from the user (coefficients to this function were set empirically). The nominal actual sound volume was also set arbitrarily.

The positions of three sound sources are adjusted in the following way. For movement in the z axis (forward/backward), at each frame, when the velocity in the respective direction goes above some pre-set threshold, the position is incrementally farther from the user in proportion to the velocity (but no farther than the pre-set limit). Below the threshold, the position is adjusted toward the user. In the case of x and y axis, the amount of rotation (of the cart, but not the user's head) between consecutive frames is used to move sound source in a similar manner proportionally.

4 Pilot Experiments and Results

Six subjects (all males, mean = 26 /SD = 2.31) were asked to experience and view a roller coaster ride content for 2.5 minutes wearing the Oculus headset. Three versions of the VR content according to the test conditions in a balanced order was administered to the subjects: (1) No sound, (2) Normal sound effect, and (3) Reverse sound effect.

The main dependent variable was the sickness level, measured using the Simulator Sickness Questionnaire (SSQ) by Kennedy et al. [4]. The before level was measured, and after each treatment, as subjects took rests (as much as was needed), they filled out the SSQ for measuring the after effects. The subcategory scores were scaled by the weight factors, as indicated in [4] (N=9.54, O=7.58, D=13.92, T=3.74) for later comparison.

Figure 3 shows the ANOVA analyzed results - in all categories including the total score, a clear trend of decrease in the sickness levels was observed for the Reverse sound flow condition while the None and Natural showed nearly equal level of after sickness (None Natural $>$ Reverse). However, no statistically significant differences were found, most probably because of the low number of subjects.

5 Discussion and Conclusion

In this poster, we investigated the effect of 3D sound emulating the reverse motion flow for lessening the VR sickness in hopes of using the technique as a supplement the methods of visually manipulating the motion information in the future. The pilot experiment showed positive results, but not to a statistically significant level possibly due to the low number of subject data. In addition, we were not able to observe the positive effect toward sickness reduction by adding natural sound effects either, contrary to some of the prior results [2], [7]. While the approach was test only with the roller coaster example, the basic framework is applicable to other VR contents. The experimental results did not indicate the possible confusion in the vestibular sense (since the stimulation is given close to the sound processing part of the ear), however, further in-depth experimentation is needed. The work hints on the possibility and potential of manipulating the "multimodal" motion information to supplement that of the visual in relieving VR sickness symptoms.

References

[1] P. Budhiraja, M. R. Miller, A. K. Modi, and D. Forsyth. Rotation blurring: use of artificial blurring to reduce cybersickness in virtual reality first person shooters. *arXiv preprint arXiv:1710.02599*, 2017.

[2] S. D'Amour, J. E. Bos, and B. Keshavarz. The efficacy of airflow and seat vibration on reducing visually induced motion sickness. *Experimental brain research*, 235(9):2811–2820, 2017.

[3] A. S. Fernandes and S. K. Feiner. Combating vr sickness through subtle dynamic field-of-view modification. In *2016 IEEE symposium on 3D user interfaces (3DUI)*, pp. 201–210. IEEE, 2016.

[4] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, 3(3):203–220, 1993.

[5] J. LaViola Jr. A discussion of cybersickness in virtual environments. *ACM Sigchi Bulletin*, 32(1):47–56, 2000.

[6] S. H. Park, B. Han, and G. J. Kim. Mixing in reverse optical flow to mitigate vection and simulation sickness in virtual reality. In *CHI Conference on Human Factors in Computing Systems*, pp. 1–11, 2022.

[7] Y. Sawada, Y. Itaguchi, M. Hayashi, K. Aigo, T. Miyagi, M. Miki, T. Kimura, and M. Miyazaki. Effects of synchronised engine sound and vibration presentation on visually induced motion sickness. *Scientific reports*, 10(1):1–10, 2020.

[8] C. Wienrich, C. K. Weidner, C. Schatto, D. Obremski, and J. H. Israel. A virtual nose as a rest-frame-the impact on simulator sickness and game experience. In *2018 10th international conference on virtual worlds and games for serious applications (VS-Games)*, pp. 1–8. IEEE, 2018.