RoadVR: Mitigating the Effect of Vection and Sickness by Distortion of Pathways for In-Car Virtual Reality

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ABSTRACT

We explore a method to reduce motion sickness and allow people to use virtual reality while moving in vehicles. We put forth a usage scenario where the target VR content is based on constant road navigation so that the actual motion can enhance the VR experience. The method starts with a virtual scene and objects around an infinitely straight road. The motion of the vehicle is sensed by the GPS and IMU module. The sensed motion is reflected in a way that the virtual scene is navigated according to the vehicle motion, and its pathways distorted such that the virtual motion has a near-identical optical flow pattern to the actual. This would align the user's visual and vestibular sense and reduce the effect of vection and motion sickness. We ran an pilot experiment to validate our approach, comparing the before and after sickness levels with the VR content (1) not aligned to the motion of the vehicle and (2) aligned by our method. Our preliminary results have shown the sickness was reduced significantly (but not eliminated to a negligible level yet) with our approach.

CCS CONCEPTS

• **Human-centered computing → Systems and tools for interaction design**.

KEYWORDS

Virtual Reality, Motion Sickness, Simulator Sickness, Vection, Navigation, Distortion

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1 INTRODUCTION

People spend a considerable amount of time in transportation to go to work and travel almost every day. Virtual reality can be a media that can be used effectively in vehicles for various purposes like entertainment and on-line meeting. However, one major obstacle to adopting VR at the consumer level has been the issue of sickness. The use of VR in vehicles could exacerbate the situation as many people already experience motion sickness while being transported in vehicles. The root of the sickness problem is the sensory mismatch between visual feedback and vestibular sense [3].

Therefore, by aligning the movement of the vehicle (and thereby that of the user) and that in the VR content can possibly mitigate the effect of the sensory mismatch and reduce sickness following [1, 4]. We propose to flexibly fit the VR content to an arbitrary movement of the vehicle and validate the reduced level of sickness. In essence, the approach distorts the pathways in the virtual reality content in real time and reflects the actual movement of the vehicle such that the visual feedback matches the corresponding movement as sensed by the user's vestibular sense (see Figure 2).

2 ROADVR

Figure 1 shows the overall system configuration of RoadVR and depicts the typical usage situation. RoadVR would be used by a person in the passenger seat, wearing a VR headset.

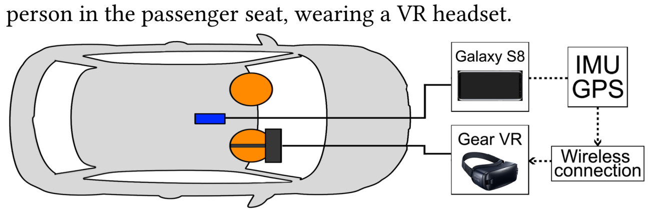

Figure 1: The overall system configuration of RoadVR.

2.1 Sensing and Stabilizing Vehicle Motion

Apart from user movement, vehicle motion is detected separately by the vehicle motion sensor module equipped with GPS (1HZ) and IMU (60HZ). The GPS was used to do away with having to connect to the OBD of different cars. Sensor values are received over the wireless connection to the user's smartphone (60HZ) where they were filtered and used to estimate the car speed and rotational velocities/accelerations. Then the user's rotational movement as sensed from the user's smartphone is subtracted by those of the vehicle motion, as to isolate the user's own rotation so that the user can stably look around the virtual space, unaffected by the vehicle rotation.

2.2 Distorting Virtual Scene by Vehicle Motion

The motion of the vehicle sensed by the GPS/IMU module is reflected in a way that the virtual scene is navigated according to the vehicle motion, by distorting the originally straight pathways appropriately, that is, e.g. when turning right, the roads will be distorted to curve to the right. This in turn would align the vehicle motion to the user's expectation, the corresponding optical

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flow (see Figure 3) pattern, and ultimately the visual and vestibular senses themselves. Equation (1) and (2) show how the movement profile of the vehicle affects the distortion of the 3D road model.

$$v' = v + k_i * d_i, \tag{1}$$

$$d_i = \tan r_i * d^2/s, \tag{2}$$

where v corresponds to the original 3D vertex of the model; v' the distorted vertex; r_i, the rotational velocity; s, the car speed; d, depth to the vertex from the viewpoint; k_i, an arbitrary scale adjusting constant; and i, the x or y dimension. At every frame, each vertex in the scene is adjusted and displaced by three factors, the rotational velocity, the car speed and the depth of the vertex from the viewpoint. Only the x and y dimensions of the positions are affected (that is the distortion occurs only in the left-right and top-down directions). The arbitrary constant k_i adjusts the scale of the distortion in the respective dimensions (set to $kx = 1.0$, $ky = 0.15$ after trials and errors). Figure 2 shows the effects of some of these distortion parameters.

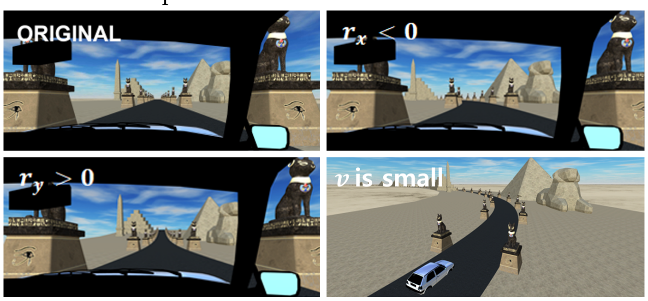

Figure 2: The effects of the rotational and car speed to the visual distortion of pathway scene.

Figure 3: The similar optical flow between the actual scene and the corresponding virtual space (curving to the right).

3 EXPERIMENT

The Experiment was designed as a one-factor (2 levels) within-subject single measure. The factor was whether the distortion for motion synchronization was applied or not. In the first baseline condition (Base), the user viewed a constant navigation VR content whose navigation paths were different from that of the vehicle motion, using the aforementioned set-up. In the second condition (Synch), the user viewed the initially straight-road virtual space dynamically distorted and moved in synchronization to the vehicle motion. We mainly measured, as the main dependent variable, the before and after levels of motion/simulator sickness using the SSQ by Kennedy et al. [2].

A total of 15 paid (KRW 10,000) subjects (14 men and 1 women between the ages of 23 and 25, mean = 24.666 / SD = 0.617) participated in the experiment. Before experiencing the VR content, the subject rode in the car for 5 minutes (around not so crowded city streets) and filled out the motion sickness questionnaire to measure the "Before VR" level. Then in the main experiment, the subject sat in the passenger side, wore the GearVR headset, and started to view the VR content (infinite road with Egyptian landmarks) as the car started (driven by the helper) to move around a rectangular course in local streets (City of Asan, Chungchung Province, Korea), 5 times (5.5 km), at an average speed of 60 km/hr, which took about 5 minutes. Considering the learning effect, the conditions were experienced in a balanced order between subjects. Our purpose was to confirm the hypothesis that a significant effect of reduced level of sickness existed by the motion synchronization.

4 RESULTS

The main dependent variable in this study was just the levels of the motion/simulator sickness for the "Before VR" and two after conditions – "Base" and "Synch". The sickness was assessed in three subcategories – Oculomotor (O), Disorientation (D), and Nausea (N). Figure 4 shows the results of the ANOVA with Tukey HSD, where statistically significant differences were found among the conditions: Before VR < Synch < Base.

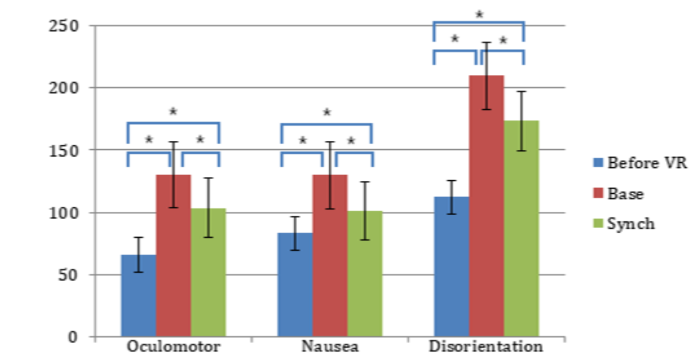

Figure 4: The average levels (with standard errors) of sickness among the three conditions. Significant effects are found among all three conditions and categories (O, N, D).

5 CONCLUSION

We presented RoadVR, a method to synchronize the motion of the car to allow the passenger to view VR contents with the reduced level of motion/simulator sickness. The method is based on dynamically distorting the pathways (and the neighboring objects) of the virtual scene such that it emulates the actual optical flow and match the vestibular sense as close as possible. However, even after the reduction, the sickness level was still in the "significant" range [2]. Thus, additional provisions will be needed to further suppress it such as peripheral blurring or dynamic FOV adjustment. More accurate estimation of the vehicle motion, reducing the latency (e.g. by the use of OBD) and addressing the gyro drift and rolling motion should further lower the sickness level. In its current form, the method is restricted to road/street level navigational VR contents such as racing games. However, we are working on ways to extend our approach to mix in stationary VR content (e.g. on-line meetings).

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