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Presenting Climbing/Descending Sensation with Visual image and Horizontal Acceleration

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Abstract

In this study, a method for generating the sensation of driving uphill and downhill using an electric wheelchair equipped with a spherical display was proposed as a solution to the problem of driving uphill when moving through a VR space using an RDD using an electric wheelchair equipped with a spherical display. It was hypothesized that four elements are important for generating the sensation of driving uphill using an electric wheelchair equipped with a spherical display without adding any special mechanisms: "horizontal acceleration," "movement speed in the VR space," "head direction," and "viewing angle," and an evaluation experiment was conducted to verify this. As a result, significant differences were seen in all four elements when generating the sensation of driving uphill, and significant differences were seen in the three elements except horizontal acceleration when generating the sensation of driving downhill.

CCS Concepts

• ***Human-centered computing*** → *Virtual reality;*

1. Introduction

There is a method of movement in VR space called Redirected Driving (RDD) [BIPS12]. RDD for driving on flat ground has already been realized, but to express vertical movement, it is necessary to present vertical acceleration using a motion platform or the like, and the device required for this is quite large. In a previous study, Yem et al. revealed that the quality of the riding experience in VR can be improved by using vibration and vestibular sensation and the body tilt caused by a curved platform [YYUM20], but this system was difficult to combine with RDD because it stopped the wheelchair on the curved platform and moved it back and forth.

Therefore, in this study, a method was proposed to enable both flat and slope driving using a system that displays only images and horizontal acceleration, without the need for large-scale equipment.A major difference from conventional slope driving is that it is not possible to display vertical acceleration, but it was thought that a similar sensation of going up and down could be generated by combining the manipulation of vision, vestibular sensation, and somatic sensation.

Therefore, in this study, a method for generating the sensation of driving on a slope is proposed, which is possible by driving on flat ground only in the real world, without adding any other special mechanisms, using an electric wheelchair equipped with a spherical display, and the purpose is to verify its effectiveness through evaluation experiments.

2. Method for generating the sensation of riding on a slope

Due to space limitations, the article will mainly discuss the acceleration acting on the rider. When considering actual driving up/down a slope, the rider is subjected to both vertical and horizontal components of gravity, so that when going up a slope the rider's body is pressed against the seat, and when going down a slope the rider leans forward. It was hypothesized that by using an electric wheelchair, it would be possible to reproduce the sensation of being pressed against the seat and leaning forward due to vertical and horizontal acceleration.

Specifically, the horizontal portion of the gravitational acceleration exerts an inertial force on the occupant by continuously accelerating the wheelchair forward or backward. When generating the sensation of driving uphill, the wheelchair is accelerated forward to push the occupant against the seat, and when generating the sensation of driving downhill, the wheelchair is accelerated backward to make the occupant lean forward, which is thought to be how the sensation of driving uphill/downhill can be reproduced.

In addition to this, it was believed that the sensation of driving up/down a slope could be created by increasing the speed of movement in the VR space, tilting the head to look at the end of the slope, and viewing the images with a wide viewing angle.

From above discussion, it was believed that the four elements of horizontal acceleration, head direction, viewing angle, and speed of movement in the VR space were important elements for creat-

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ing the sensation of driving up/down a slope. An overview of the system is shown in Figure 1.

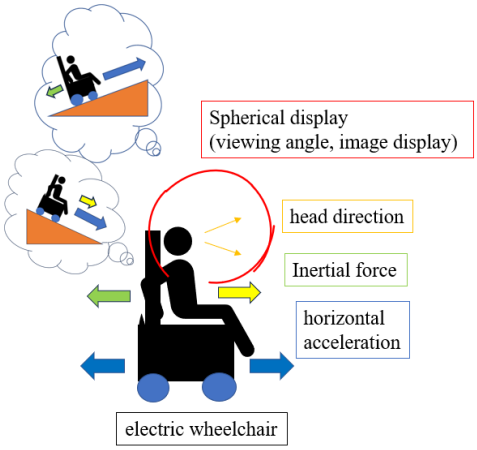

Figure 1: *system Overview*

3. Evaluation experiment

In this study, Experiment 1 was conducted to evaluate the usefulness of the four elements by generating the sensation of driving only uphill, and Experiment 2 was conducted to evaluate the usefulness by generating the sensation of driving only downhill.

In both experiments 1 and 2, participants rode in an electric wheelchair equipped with a spherical display, and each time they first experienced a standard trial that served as the basis for evaluation, and then experienced a certain pattern with different conditions to be examined. Participants were asked to answer on a five-point scale how much or how little they felt the sensation of driving uphill/downhill compared to the standard trial.

1...I don't feel it 2...I don't feel it much 3...No change 4...I feel it a little 5...I feel it

Two conditions were prepared for each of the four elements, and the subjects were asked to answer 16 combinations of these, three sets of each, for a total of 48 trials.

The order of the trials was random, and the participants in Experiment 1 were six adult men in their twenties, and in Experiment 2 were three adult men in their twenties.

4. Experimental results and discussion

The results are shown in Figure 2, 3. Of the four elements, significant differences were found for all four elements in Experiment 1, and for the three elements other than acceleration in Experiment 2.

The reason why no significant difference was observed in acceleration in Experiment 2 is thought to be because the participants did not assume the expected posture.

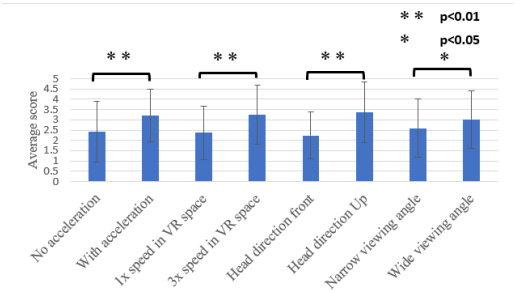

Figure 2: *Results of Experiment 1*

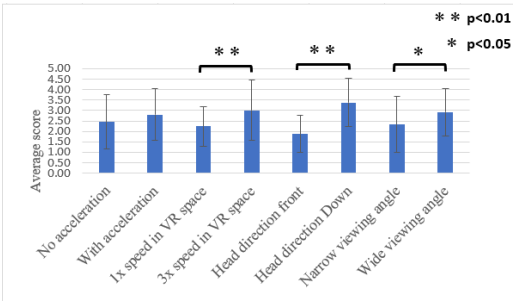

Figure 3: *Results of Experiment 2*

5. Conclusion

In this study, a method was proposed that combines horizontal acceleration and image presentation using a spherical display, making it possible to present the sensation of infinitely moving in an electric wheelchair through a VR space with ups and downs, provided that a real space of a certain size is prepared.

In the experiment, of the four proposed factors, only the acceleration condition showed no significant difference when going downhill.

In the future, in addition to re-examining the acceleration, it will also be necessary to compare it with actual driving on a slope.

Acknowledgements

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References

[BIPS12] BRUDER G., INTERRANTE V., PHILLIPS L., STEINICKE F.: Redirecting walking and driving for natural navigation in immersive virtual environments. *IEEE Transactionson Visualization and Computer Graphics 18*, 4 (Apr. 2012), 538 – 545. doi:10.1109/TVCG.2012.55. 1

[YYUM20] YEM V., YAGI R., UNNO M., MIYASHITA F.: Vibro-vestibular wheelchair with a curved pedestal presenting a vehicle riding sensation in a virtual environment. *IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)* (2020). doi:10.1109/VRW50115.2020.00215. 1