HandWindowTeleportation: Locomotion with Hand Gestures for Virtual Reality Games

Hibiki Kirihata[1] and Tomokazu Ishikawa[1,2][a]

[1] *Toyo University, 1-7-11 Akabanedai Kita-ku, Tokyo, Japan*

[2] *Prometech CG Research, 3-34-3 Hongo bunkyo-ku, Tokyo, Japan*

Keywords: Virtual Reality, Point and Teleport, Hand Tracking, Hand Gesture.

Abstract: This study designs and evaluates a novel one-handed gesture-based control method for teleportation within a VR game space. For three different stages, we measured travel time, number of moving maneuvers, and accuracy in achieving checkpoints, and used two questionnaires, NASA-TLX and SUS, to evaluate the subject's workload and the usability of proposed system. It was suggested that the proposed teleportation method using hand gestures is appropriate for games that require agility, such as action games, and is less tiring and has better ease of use than the previous method and a method on existing products.

1 INTRODUCTION

Recent technological developments have made virtual reality (VR) head-mounted displays (HMDs) more widespread and affordable. An increasing number of HMDs utilize the inside-out method, do not use a controller, and are equipped with hand-tracking functions. With plans to release HMDs without controllers, hand tracking will become an important method of operation in the XR (Extended Reality) environment in the future. Indeed, there is a lot of research on manipulating virtual objects using hand tracking (Schäfer et al., 2022; Hameed et al., 2021; Pei et al., 2022).

Because many VR applications and games involve frequent movement, optimizing this behavior is an important research topic. VR experiences using VR HDMs would be more highly immersive if they were operated by actually walking, but this is often difficult due to physical limitations. Therefore, a method to move around in VR space without having to walk in real space: Point And Teleport was proposed. Conventional VR HMDs always have a controller and are assumed to be operated via a controller. As mentioned previously, in light of the information on future HMD releases, a movement method based on hand tracking without a controller is needed. There are few research examples of movement methods using hand tracking, and to the best of our knowledge, there are few experiments comparing the improvement of VR experience by different movement methods. In particular, there are almost no examples of testing whether it is easy to move while performing actions other than moving, such as attacking an enemy, that are intended to be used in actual games. Therefore, in this study, assuming that it will be used in a game, we implement a moving method that is quicker and more intuitive to use, and compare our method to a previous method and a method used in an existing product.

[a] https://orcid.org/0000-0002-9176-1336

2 RELATED WORKS

In this section, we describe previous researches, classifying them into two categories: moving methods in VR space and moving methods using hand tracking.

2.1 Moving Methods in VR Space

Bolte et al. proposed a method called "jumper metaphor," which supports actual walking for short distances and virtual jumping for longer distances (Bolte et al., 2011). According to evaluations, this method allows for more effective exploration compared to actual walking and has little effect on spatial perception.

The research by Bozgeyikli et al. presented a new locomotion technology called "point and teleport" and compared it to the gait simulation and joy-

Kirihata, H. and Ishikawa, T.
HandWindowTeleportation: Locomotion with Hand Gestures for Virtual Reality Games.
DOI: 10.5220/0012472900003660

In *Proceedings of the 19th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2024) - Volume 1: GRAPP, HUCAPP and IVAPP*, pages 170-176
ISBN: 978-989-758-679-8; ISSN: 2184-4321

sticks that are normally used (Bozgeyikli et al., 2016). With this technology, the user simply points to where they want to go in the virtual world and is teleported to that location. One major advantage is that there is no visible parallel movement, which is expected to reduce the likelihood of motion sickness. 16 users participated in the experiment, suggesting that while ”point and teleport” is a fun and user-friendly locomotion technique, the additional directional component degrades the user experience.

Funk et al. proposed and evaluated three different point-and-teleport techniques that allow the user to specify the target orientation during teleportation (Funk et al., 2019). The results showed that the teleportation technique with directional instructions increased the average teleportation time but decreased the need to correct the orientation after teleportation.

Rantala and Kangas highlighted that teleportation in VR space may limit spatial awareness because the method of movement is not continuous (Rantala et al., 2021). Teleportation is well suited for VR controllers and can minimize simulatorsickness (motion sickness), but may reduce spatial awareness compared to continuous movement. The goal of their study was to develop a continuous, controller-based movement technique and to test whether it supports spatial awareness. Rantala and Kangas introduced two new techniques, “slider” and “grab,” and compared them to teleportation. Results showed that “slider” and “grab” were significantly faster than teleportation, and that they caused significantly less simulator sickness than teleportation. Furthermore, it was concluded that the continuous technique provided better spatial awareness than teleportation.

Cmentowski et al. propose a novel augmented walking approach for virtual reality games that presents a virtual tunnel covering the entire travel distance (Cmentowski et al., 2022). This virtual tunnel hides the visual flow from the applied motion acceleration, while the actual accelerated motion is visible through the tunnel wall windows. According to the evaluation, this approach avoids cybersickness and at the same time improves physical activity and preserves presence.

Considering that additional cognitive load could negatively affect performance for the method proposed by Funk et al. (Funk et al., 2019), Mori et al. proposed a new P&T design: “points to teleport” (P2T) (Mori et al., 2023). They also reevaluated the accuracy of P&T with the user standing and sitting.

In these studies, researchers are experimenting with operability by designing a UI that mainly uses a VR controller when moving and presents the teleportation destination on a virtual environment. In view of the future development of VR devices, we will investigate a method of teleportation using hand gestures without a controller.

2.2 Moving Methods Using Hand Tracking

Focusing on a technique to control teleport-type movement with hand gestures, Schäfer et al. proposed a way for users to move in VR using only their hands; two both-handed and two one-handed techniques were evaluated in 21 participants according to effectiveness and efficiency and user preference (Schäfer et al., 2021). When performing hand gestures, there was no clear difference between using both hands or only single hand, so they concluded that one hand alone can comfortably and effectively move through the virtual world.

The study by Neamoniti and Kasapakis presents preliminary evaluation results on the use of motion tracking versus hand tracking in IVR (Immersive Virtual Reality) games (Neamoniti and Kasapakis, 2022). Results indicate that while hand tracking has lower levels of ease of use and learning effectiveness, it does not affect the overall game experience as compared to motion controllers.

Lesaca et al. conducted an experiment comparing four teleportation methods for everyday movement in VR (Lesaca et al., 2022). The results of the experiment show that in general use, experienced VR users prefer to use their hands to control the virtual arc and indicate the location and direction they wish to teleport. However, Lesaca et al. concluded that the step-by-step teleportation method in the direction of gaze supports more natural movement and may encourage shorter travel paths, but instead takes longer travel times.

With reference to the above related works, we design and evaluate a hand gesture-based moving method that can be used in games, which is better than the previous methods.

3 PROPOSED METHOD AND EXPERIMENT

The hand gesture of the moving method proposed in this research is designed with an emphasis on the ability to move instantly, at the user’s will, to the coordinates targeted by the user. We designed hand gestures inspired by ”The Grab-a-Scope” is one of gadgets which Doraemon has. The index finger and thumb which are spread out liken to a scope, and the

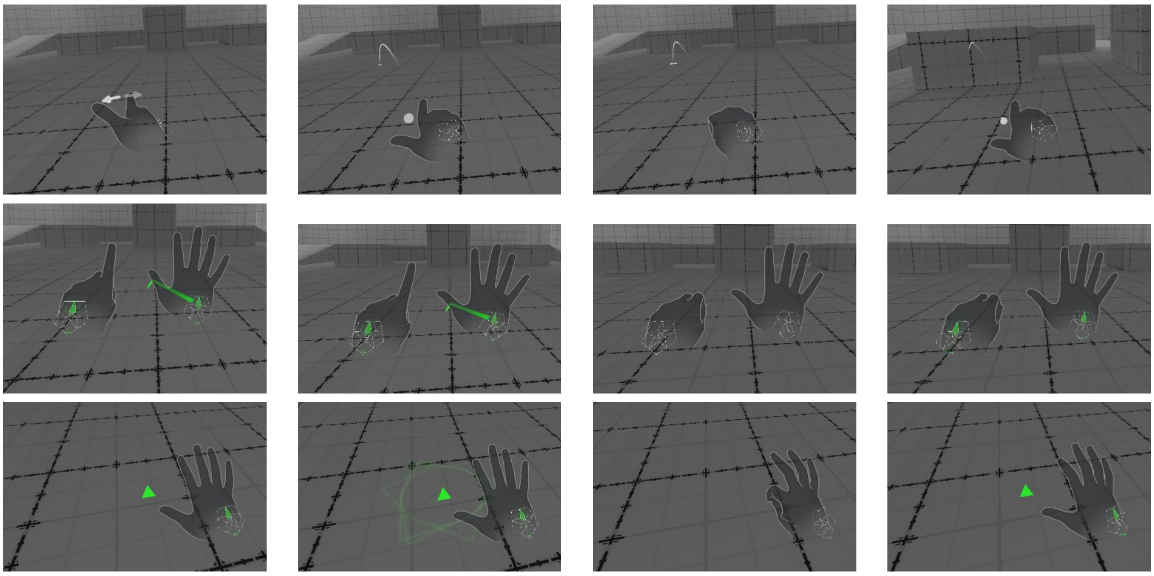


Figure 1: Image sequences when a hand gesture for each moving method is performed. Top: Oculus Integration, middle: Two-Hand Palm and bottom: “HandWindow” (ours).

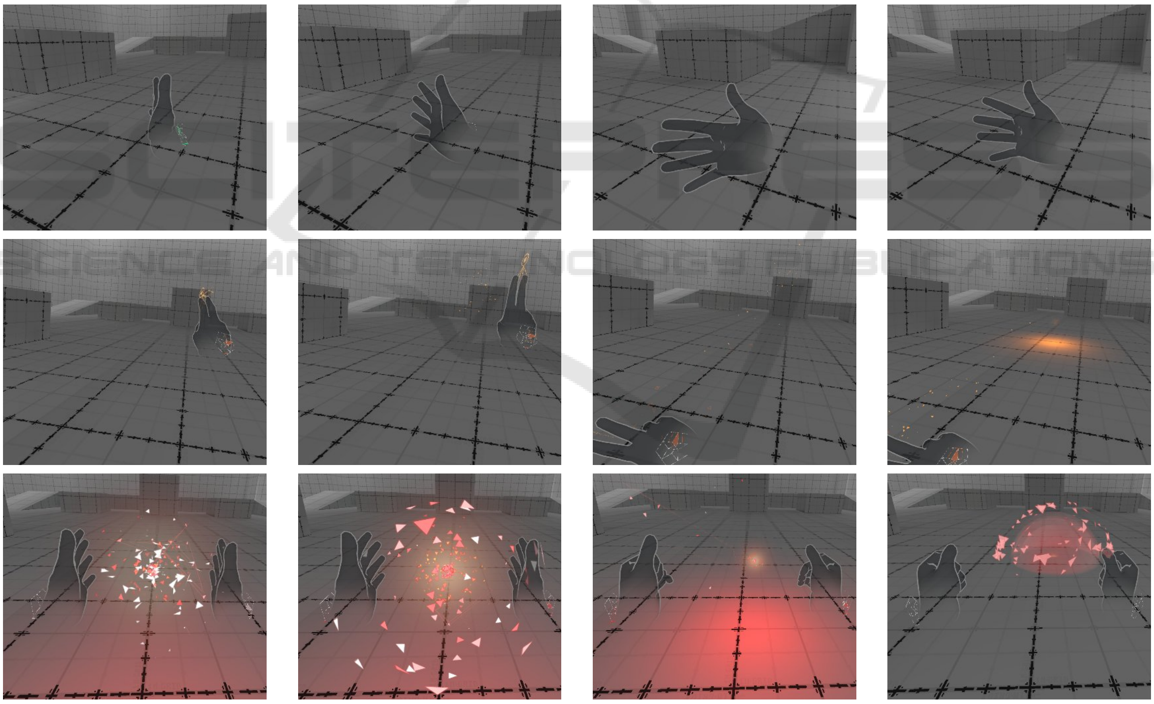


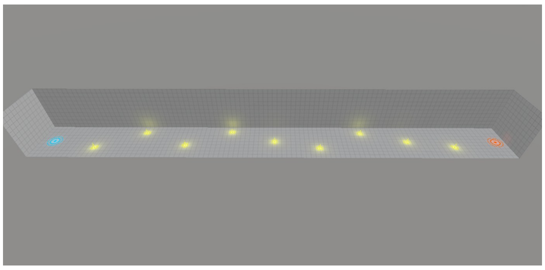
Figure 2: Image sequences when hand gestures other than movement are performed. Top: turning, middle: normal attack and bottom: charge attack.

user pinch such as plucks out the landscape, which results in moving to its coordinate. We call this teleportation method using hand gesture “HandWindow”. Our method employs a user interface that specifies the teleportation destination as a straight line from the camera coordinates to the ground surface connecting the midpoints of the thumb and index finger. We considered that a straight guideline would make it easier for the user to aim at the destination compared to the previous method. By touching the index finger and thumb, the user decides to move. Using this hand gesture, we expect the user to have the experience of picking the place at hand.

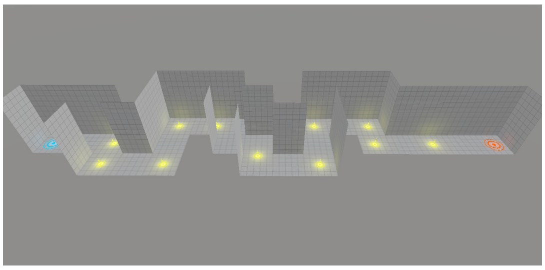
We implement a system to identify hand gestures using hand tracking running on the Meta Quest series. We employ the framework provided by the Oculus Integration to recognize the user's hand. The angle of the finger joints of the hand on the virtual, which is recognized by Oculus Integration, is acquired to determine how bent the fingers are at that angle. Using the above methods, we implement three different moving methods (Oculus Integration, a previous method and "HandWindow"), a turning method, and two attack methods on a VR game. In Oculus Integration, an arc-shaped guideline is drawn from between the index finger and thumb to select the teleportation destination. The decision is made by touching the index finger and thumb, and the user teleport there. As a previous method for comparison, we implemented Two-Hand Palm which is the method proposed by Schäfer et al. (Schäfer et al., 2021). In the Two-Hand Palm, an arc-shaped guideline is output from the palm of the hand to select the teleportation destination. The user executes teleportation by bending the index finger of the other hand. For each moving gesture, image sequences are shown in Figure 1.

To conduct the experiment in combination with an action game, hand gestures are assigned to actions required in addition to the moving method. Turning is a directional change in the player's direction; by sweeping the space below the eye with the palm, the player rotates in the direction swept by the palm. The two types of attacks are the normal attack, which involves waving the hand with the index and middle fingers held up, and the charge attack, which involves forming a bowl with both hands and firing an energy shot. Normal attacks can be fired in rapid succession but are less powerful and difficult to gesture. Charge attacks take longer to strike but are more powerful and can be used with a simple gesture. It is designed so that those who can do a normal attack will use it as their main tool, and those who have difficulty with it will use a charge attack. Images sequences of the turning and attacking gestures are shown in Figure 2.

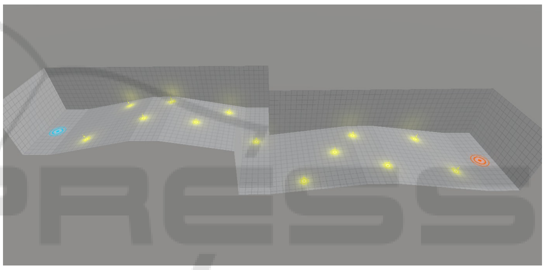
Experimental participants were asked to use three different moving methods on the implemented original VR game, and their movement times and movement coordinates were recorded. The stages for the moving experiment were prepared in three patterns: a flat and straight stage, a narrow and bent stage, and a stage with a difference in height. One stage for the combat experiment was prepared. In the combat stage, the player is limited to moving range. The appearance of the experimental stage is shown in Figure 3 and Figure 4 shows the combat stage. Users are asked to play in two modes: one in which locations to be passed are indicated as checkpoints, and the other in which they are free to reach the goal. That is, we ask one user to play 21 different experimental patterns. From this measurement data, the total travel time from start to goal, the number of moving operations, and the accuracy of reaching checkpoints



(a) Stage 1: a flat and straight stage



(b) Stage 2: a narrow and bent stage



(c) Stage 3: a stage with a difference in height

Figure 3: Appearance of each stage. A red marker indicates the start point, a blue marker indicates the goal point, and yellows marker indicate checkpoints that the user must pass through.

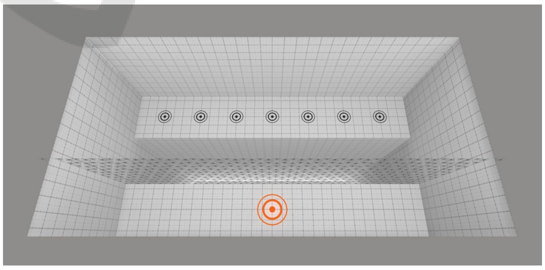


Figure 4: Appearance of stage 4. A red marker indicates the start point, and blacks marker indicate the locations where enemies appear. The black wall prevents the player from going to the location where the enemy appears.

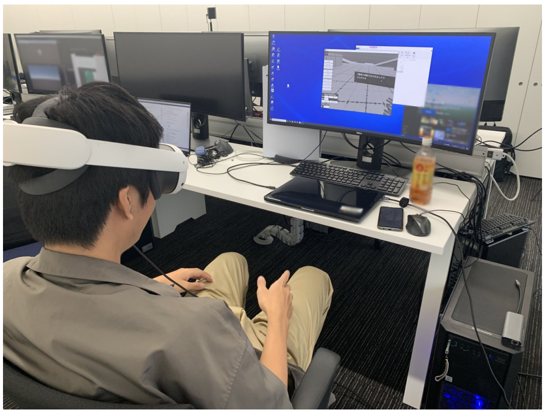


Figure 5: During the experiment. The subject sits in a chair and plays a game in VR, using only hand gestures to rotate and move without changing the position or direction of the body.

are calculated and used for evaluation. After using the moving methods, the respondents were asked to evaluate each of the moving methods in a questionnaire that included NASA-TLX (NASA Task Load Index) (Hart and Staveland, 1988) and SUS (System Usability Scale) (Brooke, 1995). Participants also answer to respond to the best method of travel used.

We use a PC with OS: Windows 10 Home 64bit, CPU: Intel® Core™ i7-10700K CPU @ 3.80GHz, RAM: 16GB and GPU : NVIDIA GeForce RTX 2080 SUPER 8GB and Meta Quest 3 for our experiments. We develop a game for experiment on Unity.

4 RESULTS AND DISCUSSION

11 male university students in their teens and twenties majoring in information science were asked to cooperate in the experiment. Only two of them had never experienced VR. The order of movement methods in the experiment was randomized to avoid differences in training level. The Figure 5 shows the situation during the experiment.

First, the results for total travel time and number of movements are shown in the Figure 6 and 7 for the experiment in which travel was performed regardless of checkpoints. Averaging the arrival time of all stages, the Oculus Integration, Two-Handed Palm, and the proposed method took 15.28 s, 15.38 s, and 11.60 s, respectively. We found the possibility of reducing travel time for any stage compared to the existing method. The proposed method has a small variance for all stages, is equally easy to use for all users, and takes less time in tight and winding places.Therefore, we can mention that our method is a method with a small turnaround. However, using the

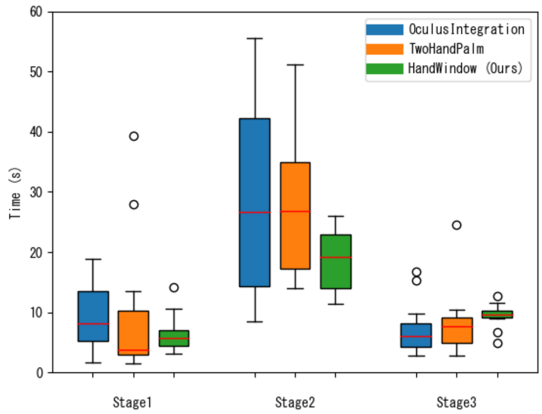


Figure 6: Box plots of total travel time in experiments in which travel is independent of checkpoints.

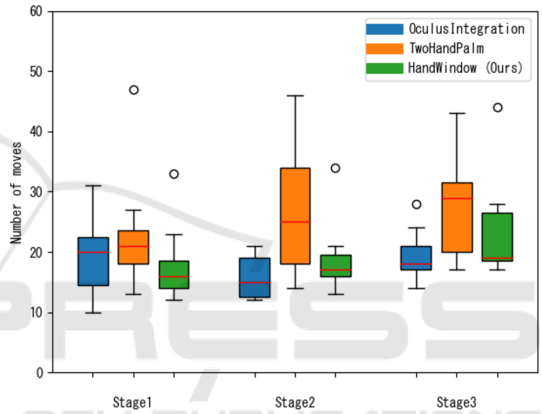


Figure 7: Box plots of number of moving method in experiments in which travel is independent of checkpoints.

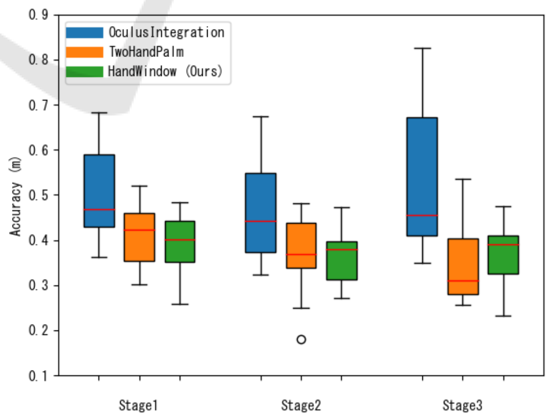


Figure 8: Accuracy comparison of move coordinates against checkpoint coordinates.

proposed method took longer than the other methods for the stages with height differences. We consider that this result is caused by the fact that only “HandWindow” specifies the teleportation destination as a straight line, not as an arc. If the destination is spec-

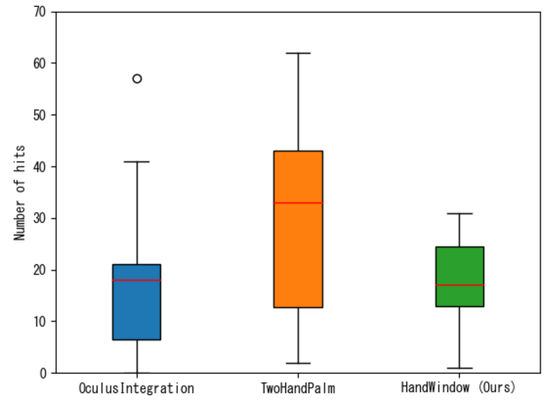


Figure 9: Results of counting the number of times a person is hit in battle.

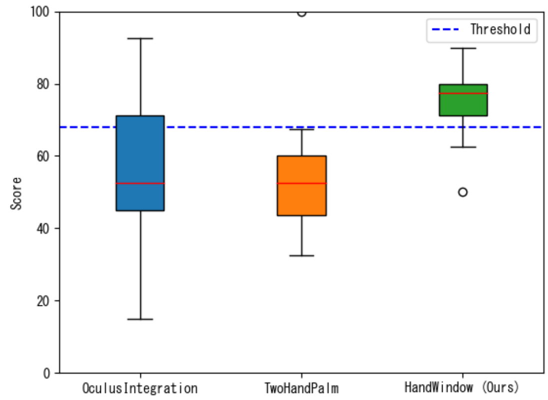


Figure 11: Box plots of SUS scores. The blue broken line shows the average SUS value of 68.

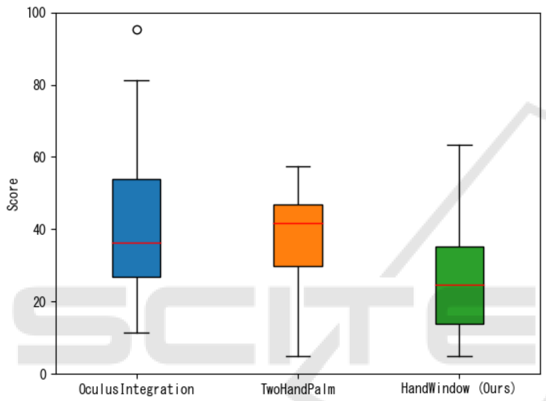


Figure 10: Box plots of NASA-TLX scores.

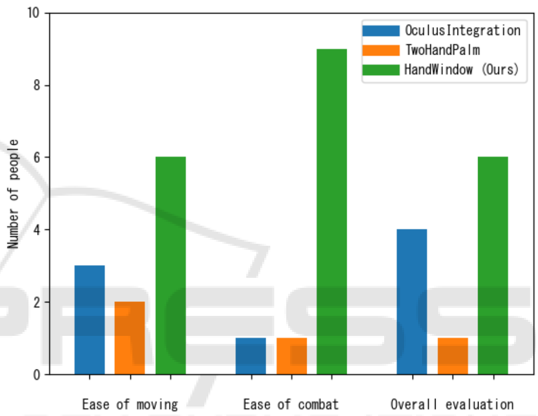


Figure 12: Results of asking experimental participants to vote for the best 1 of the 3 moving methods in terms of "ease of moving", "ease of combat", and "overall evaluation".

ified as an arc, as in the previous method, it is possible to teleport to a location where the player cannot see the ground. However, the number of movements tended to be less than for other methods.

Next, the accuracy results are shown in Figure 8 for an experiment in which the participants are asked to move through the checkpoints sequentially. The RMSE (Root Mean Squared Error) was used to evaluate the degree of error in the transition destination by the moving method with respect to the target checkpoint. We conclude that the proposed method is highly accurate because the variance is small and the mean is also small.

The number of times a player was hit by bullets in a battle was counted as a way to check if the method is suitable for movement in an action game. The method is easier to avoid if the number of being bombed times is small. As you can be seen in the Figure 9, the proposed method reduces the number of being shot. Thus we can conclude that it is highly compatible with games that require agility, such as action games.

The NASA-TLX scores for each moving method are shown in Figure 10. The higher the NASA-TLX score, the higher the subject's fatigue level. The box plots show that the proposed method is less fatiguing than the other two methods. The mean NASA-TLX scores were 43.82, 37.76, and 27.94 for the Oculus Integration, Two-Handed Palm, and the proposed method, respectively.

The results of the SUS scores are shown in the Figure 11; the higher the SUS score, the better the usability. A score above 68, the average of SUS, is considered good usability, and a score above 80 is considered excellent usability. The SUS scores were 55.91, 55.00, and 75.45 for the Oculus Integration, Two-Handed Palm, and "HandWindow", respectively. The proposed method has a better SUS score than the other methods, with the average being close to 80, and can be said to have excellent usability.

Finally, the Figure 12 shows the results of having the participants vote for the best 1 among the 3 movement methods in terms of "ease of movement," "ease of combat," and "overall evaluation". The results showed that the proposed method was the best for all items. This result is considered to be voted by the subjects as an overall evaluation of the above-mentioned factors.

5 CONCLUSIONS AND FUTURE WORK

In this research, we proposed a new single handed gesture method for instantaneous movement within VR space. The hand gesture implemented as the proposed method was designed for action games, respecting the user's initiative and allowing for agile movement. In order to compare the proposed method with the existing methods and the methods used in existing products, users were tested on three stages for teleportation. Quantitative evaluations such as time from start to finish, number of actions, accuracy on each checkpoint NASA-TLX and SUS, as well as subjective evaluations were conducted. For all the items, the proposed method obtained positive results, and we consider that the small turnaround in particular makes the proposed method more friendly to action games.

We would like to discuss some improvements to the proposed "HandWindow". First, the problem that only the floor can be specified as the destination, making it difficult to move depending on the terrain, should be resolved. We think it is necessary to take countermeasures such as making a downward judgment when it hits a wall, or performing a sphere cast when a ray cast is performed and movement is not possible. There was an opinion that the UI should display not only the destination but also a line from the hand to the destination, which will be improved.

ACKNOWLEDGEMENTS

This work was supported by Toyo University Top Priority Research Program.

REFERENCES

Bolte, B., Steinicke, F., and Bruder, G. (2011). The jumper metaphor: an effective navigation technique for immersive display setups. *Proceedings of virtual reality international conference*, 1(2).

Bozgeyikli, E., Raij, A., Katkoori, S., and Dubey, R. (2016). Point & teleport locomotion technique for virtual reality. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play*, CHI PLAY '16, page 205–216, New York, NY, USA. Association for Computing Machinery.

Brooke, J. (1995). SUS: A quick and dirty usability scale. *Usability Eval. Ind.*, 189.

Cmentowski, S., Kievelitz, F., and Krueger, J. H. (2022). Outpace reality: A novel augmented-walking technique for virtual reality games. *Proc. ACM Hum.-Comput. Interact.*, 6(CHI PLAY).

Funk, M., Müller, F., Fendrich, M., Shene, M., Kolvenbach, M., Dobbertin, N., Günther, S., and Mühlhäuser, M. (2019). Assessing the accuracy of point & teleport locomotion with orientation indication for virtual reality using curved trajectories. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, page 1–12, New York, NY, USA. Association for Computing Machinery.

Hameed, A., Perkis, A., and Möller, S. (2021). Evaluating hand-tracking interaction for performing motor-tasks in VR learning environments. In *2021 13th International Conference on Quality of Multimedia Experience (QoMEX)*, pages 219–224.

Hart, S. G. and Staveland, L. E. (1988). Development of NASA-TLX (task load index): Results of empirical and theoretical research. In Hancock, P. A. and Meshkati, N., editors, *Human Mental Workload*, volume 52 of *Advances in Psychology*, pages 139–183. North-Holland.

Lesaca, D., Cheung, H., Jena, T., and Cliburn, D. (2022). Comparing teleportation methods for travel in everyday virtual reality. In *2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pages 238–242.

Mori, S., Hashiguchi, S., Shibata, F., and Kimura, A. (2023). Point & teleport with orientation specification, revisited: Is natural turning always superior? *Journal of Information Processing*, 31:392–403.

Neamoniti, S. and Kasapakis, V. (2022). Hand tracking vs motion controllers: The effects on immersive virtual reality game experience. In *2022 IEEE International Symposium on Multimedia (ISM)*, pages 206–207.

Pei, S., Chen, A., Lee, J., and Zhang, Y. (2022). Hand interfaces: Using hands to imitate objects in AR/VR for expressive interactions. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, CHI '22, New York, NY, USA. Association for Computing Machinery.

Rantala, J., Kangas, J., Koskinen, O., Nukarinen, T., and Raisamo, R. (2021). Comparison of controller-based locomotion techniques for visual observation in virtual reality. *Multimodal Technologies and Interaction*, 5:31.

Schäfer, A., Reis, G., and Stricker, D. (2021). Controlling teleportation-based locomotion in virtual reality with hand gestures: A comparative evaluation of two-handed and one-handed techniques. *Electronics*, 10(6).

Schäfer, A., Reis, G., and Stricker, D. (2022). Comparing controller with the hand gestures pinch and grab for picking up and placing virtual objects. In *2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pages 738–739.