Thumble: One-Handed 3D Object Manipulation Using a Thimble-Shaped Wearable Device in Virtual Reality

Changsung Lim*†
School of Computing, KAIST
Daejeon, Republic of Korea
cslim@kaist.ac.kr

Jina Kim*
Culture Technology, KAIST
Daejeon, Republic of Korea
jina1190@kaist.ac.kr

Myung Jin Kim*
Industrial Design, KAIST
Daejeon, Republic of Korea
dkmj@kaist.ac.kr

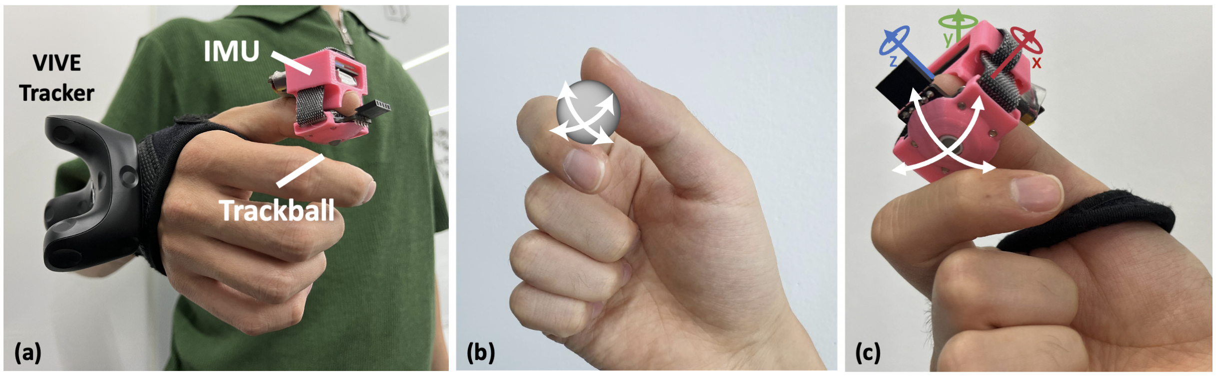

Figure 1: (a) Thumble and its key components. (b) Metaphor - rotating a tiny object (c) Interaction of Thumble

ABSTRACT

Conventional controllers or hand-tracking interactions in VR cause hand fatigue while manipulating 3D objects because repetitive wrist rotation and hand movements are often required. As a solution to this inconvenience, we propose Thumble, a novel wearable input device worn on the thumb for modifying the orientation of 3D objects. Thumble can rotate the 3D objects depending on the orientation of the thumb and using the thumb pad as an input surface on which the index finger rubs to control the direction and degree of rotations. Therefore, it requires minimal motion of the wrist and the arm. Through the informal user study, we collected the subjective feedback of users and found that Thumble has less hand movement than a conventional VR controller.

CCS CONCEPTS

• **Human-centered computing** → **Interaction techniques**; **Virtual reality**.

KEYWORDS

3D object manipulation, interaction design, virtual reality

*All authors contributed equally to this research (alphabetical order).
†Corresponding author

UIST '22 Adjunct, October 29-November 2, 2022, Bend, OR, USA

ACM ISBN 978-1-4503-9321-8/22/10.
https://doi.org/10.1145/3526114.3558703

ACM Reference Format:
Changsung Lim, Jina Kim, and Myung Jin Kim. 2022. Thumble: One-Handed 3D Object Manipulation Using a Thimble-Shaped Wearable Device in Virtual Reality. In *The Adjunct Publication of the 35th Annual ACM Symposium on User Interface Software and Technology (UIST '22 Adjunct), October 29-November 2, 2022, Bend, OR, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3526114.3558703

1 INTRODUCTION

3D object manipulation is one of the most common tasks required in virtual environments [1]. In commercial virtual reality(VR) systems, manipulating 3D virtual objects involves handheld controllers or hand-tracking systems. However, conventional interactions of these methods have been shown to require a clutching or pinching gesture to rotate. Thus, they cause hand fatigue. Moreover, a handheld device prevents using the hand for other purposes.

Previous works suggested mid-air object manipulation [1–3], but they still require significant and repetitive hand movements to manipulate. There are also various studies using ball controllers [4–7]. It can intuitively manipulate objects according to the movement of the ball. However, it limits the freedom of the hand in use, and there is a risk of dropping it. In summary, existing studies do not simultaneously provide less hand movement and freedom.

Therefore, our goal is to solve the problems of the existing methods mentioned above by designing a wearable device that manipulates an object with little movement and intuitive interaction. Lastly, we conducted an informal user study to compare the usability of Thumble and conventional VR controller.

2 INTERACTION DESIGN

We follow one key metaphor for proposing the interactions: holding and rotating a tiny object under the thumb. Since this metaphor

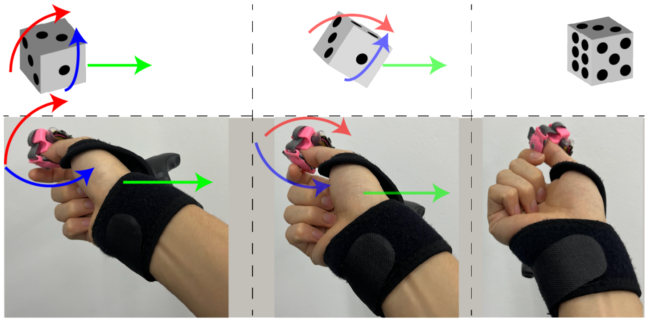

Figure 2: 3D Object rotation and translation example using Thumble. The object is translated to the right (green arrow, Tracker) while simultaneously rotating about the roll (red arrow, IMU) and pitch (blue arrow, Trackball) axes.

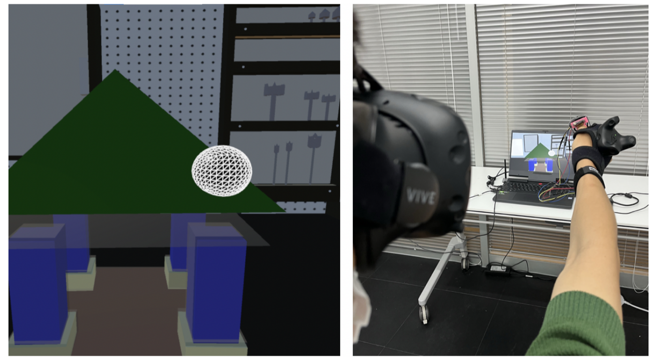

Figure 3: 3D block stacking application. In the figure on the right, the user is stacking blocks using Thumble.

is frequently used in the real world, it is intuitive and allows the user to manipulate an object with little movement in a comfortable position. Therefore, we proposed a hardware device and interaction, combining two mechanisms to implement the metaphor.

The first is to rotate the object by moving the index finger on the 2D surface under the thumbpad. Therefore, the user can rotate the object with little hand movement. We tested by attaching various sensors such as a touchpad, a joystick, and a trackball under the thumb and selected the trackball because it has the most compact size and provides tactile feedback that feels like it rotates.

The second is to rotate the object by rotating the thumb itself. We attached the IMU on the thumb. The object rotates in a one-to-one mapping according to the orientation of the thumb. Therefore, it can supplement the 2DOF of the first interaction and change the rotational axes of the 2D input.

When combining the two mechanisms, it is critical to map each trackball movement to the object's rotation correctly. While the thumb is pointing forward, the up/down movement of the trackball should be mapped to the pitch, and the left/right movement should be mapped to roll to provide intuitive movement even when the thumb orientation is changed without causing cognitive dissonance.

3 PROTOTYPE

We also made a thimble form-factor prototype called **Thumble** (Fig. 1-a) to support the designed interaction. The IMU and trackball are located at the thumb's first phalanx. The IMU placement was decided considering the higher variance in motion on the extremities and reducing physical demand on the thumb. HTC Vive Tracker 3.0 was also worn with Thumble on the user's dominant hand. However, it does not affect the object rotation.

4 EXPERIMENT

We conducted an informal user study to collect subjective feedback and figure out the effectiveness of Thumble. For this reason, we developed an application that stacks blocks using Unity (Fig. 3) and HTC VIVE Controller was selected for a baseline device. The users were asked to make a transparent template model using ten blocks of 4 types placed on the desk in random directions. They tested both devices in a comfortable sitting position.

All participants found that Thumble requires less hand movement. P1 commented, "If I get used to it, I think I can move objects with minimal movement. It seems possible to control the object by simply moving in the x, y, and z axes without turning the wrist like a VR controller. It will be able to rotate the object by moving only fingers with minimal wrist movement." P2 stated, "movement was minimized." P3 mentioned, "It will be useful when it is difficult to move the body a lot or the hand up and down." However, P1 and P3 pointed out that they felt hand fatigue, and P3 felt uncomfortable using the trackball.

Moreover, all participants provided their comments on intuitiveness. In particular, P2 stated, "Moving the VR controller feels like I was actually doing something, pointing, and holding the object rather than moving my finger." and "It seems it was a little difficult to know which I was pointing at, and to be sure which direction I am choosing." P3 felt "accuracy seems to be low." P3 was "trying to use the trackball, but it was difficult to control. It felt like it did not work the way I wanted to manipulate."

More learning time can be the solution to overcome the above problems. It can be inferred from the feedback of the participants. P1 stated, "Since I'm not used to using it, I feel like I'm putting too much strength into my entire arm when I focus on my fingers." P3 also commented, "Once I get used to it, I will feel more comfortable with less movement."

In addition, improving the prototype will have a significant impact on usability. P1 mentioned, "the trackball is so small. I have to focus on the fingertip, so it was hard to concentrate on the task."

5 CONCLUSION AND FUTURE WORK

We have built a thimble-shaped wearable device called Thumble that can manipulate the 3D object in virtual reality. Thumble implements a metaphor that rotates an object located under the thumb with the index finger. We found that it has less movement than the interaction provided by the conventional VR controller by user feedback. In a further study, we will conduct formal experiments such as performance measurement with the training session and improve the precision of the prototype comparable to the off-the-shelf VR controller.

REFERENCES

[1] Benoît Bossavit, Asier Marzo, Oscar Ardaiz, Luis Diaz De Cerio, and Alfredo Pina. 2014. Design choices and their implications for 3d mid-air manipulation techniques. *Presence: Teleoperators and Virtual Environments* 23, 4 (2014), 377–392.

[2] Daniel Mendes, Filipe Relvas, Alfredo Ferreira, and Joaquim Jorge. 2016. The benefits of dof separation in mid-air 3d object manipulation. In *Proceedings of the 22nd ACM conference on virtual reality software and technology*. 261–268.

[3] Daniel Mendes, Maurício Sousa, Rodrigo Lorena, Alfredo Ferreira, and Joaquim Jorge. 2017. Using custom transformation axes for mid-air manipulation of 3D virtual objects. In *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*. 1–8.

[4] Gary Perelman, Marcos Serrano, Mathieu Raynal, Celia Picard, Mustapha Derras, and Emmanuel Dubois. 2015. The roly-poly mouse: Designing a rolling input device unifying 2d and 3d interaction. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. 327–336.

[5] Houssem Saidi, Marcos Serrano, Pourang Irani, and Emmanuel Dubois. 2017. TDome: a touch-enabled 6DOF interactive device for multi-display environments. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 5892–5904.

[6] Bastian Schmeier, Jan Patrick Kopetz, Borge Kordts, and Nicole Jochems. 2021. Manipulating Virtual Objects in Augmented Reality Using a New Ball-Shaped Input Device. In *12th Augmented Human International Conference*. 1–8.

[7] Fabio Varesano and Fabiana Vernero. 2012. Introducing PALLA, a novel input device for leisure activities: a case study on a tangible video game for seniors. In *Proceedings of the 4th International Conference on Fun and Games*. 35–44.