SpinOcchietto: A Wearable Skin-Slip Haptic Device for Rendering Width and Motion of Objects Gripped Between the Fingertips

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

Andrea Bianchi
Industrial Design, KAIST
Daejeon, Republic of Korea
andrea@kaist.ac.kr

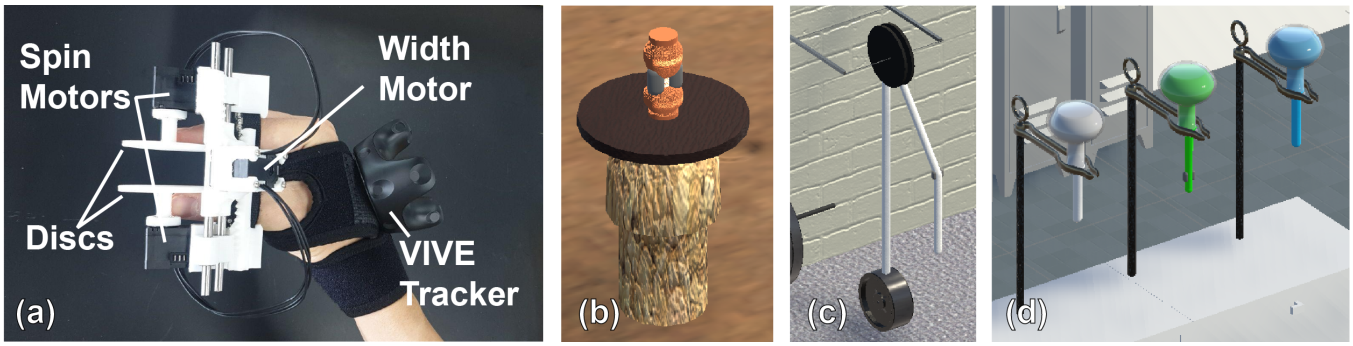

Figure 1: (a) The SpinOcchietto prototype worn on the right hand seen from the top and the (b) Potter's Wheel, (c) Fitness Center, and (d) Material Lab application scenes.

ABSTRACT

Various haptic feedback techniques have been explored to enable users to interact with their virtual surroundings using their hands. However, investigation on interactions with virtual objects slipping against the skin using skin-slip haptic feedback is still at its early stages. Prior skin-slip virtual reality (VR) haptic display implementations involved bulky actuation mechanisms and were not suitable for multi-finger and bimanual interactions. As a solution to this limitation, we present *SpinOcchietto*, a wearable skin-slip haptic feedback device using spinning discs for rendering the width and movement of virtual objects gripped between the fingertips. *SpinOcchietto* was developed to miniaturize and simplify *SpinOcchio*[1], a 6-DoF handheld skin-slip haptic display. With its smaller, lighter, and wearable form factor, *SpinOcchietto* enables users with a wide range of hand sizes to interact with virtual objects with their thumb and index fingers while freeing the rest of the hand. Users can perceive the speed of virtual objects slipping against the fingertips and can use varying grip strengths to grab and release the objects. Three demo applications were developed to showcase the different types of virtual object interactions enabled by the prototype.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; **Virtual reality**.

UIST '22 Adjunct, October 29-November 2, 2022, Bend, OR, USA
© 2022 Copyright held by the owner/author(s).
This is the author's version of the work. It is posted here for your personal use. Not for redistribution. The definitive Version of Record was published 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*, https://doi.org/10.1145/3526114.3558651.

KEYWORDS

Haptics, skin-slip, wearable, Virtual Reality, interaction technique

ACM Reference Format:
Myung Jin Kim and Andrea Bianchi. 2022. SpinOcchietto: A Wearable Skin-Slip Haptic Device for Rendering Width and Motion of Objects Gripped Between the Fingertips. 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/10.1145/3526114.3558651

1 INTRODUCTION

When we pick up an object such as a water bottle, in most cases we experience some degree of slippage occurring between the skin of our fingers and the object as we grab it. Objects do not magnetically stick to our hands as they are often portrayed in VR applications. The sensation of slippage serves as important tactile feedback to communicate whether an object is in contact with the skin, if it is in motion, and at what rate it is moving relative to the skin.

Recent research in Human-Computer Interaction (HCI) have explored the perception of skin-slip haptic feedback in VR contexts. Notably, Whitmire et al.[4] used a rotating drum attached to a VR controller to investigate surface contact and motion perception on the index finger using 1 dimensional motion control. Lo et al.[2] also used a similar approach of using a rotating ball applying skin-slip on the index finger with 2 dimensional motion control. The authors explored texture perception in relation to surface movement speeds. Mercado et al.[3] implemented a different approach, using a robot arm with an end effector responding to the motion of a tracked index finger to render an infinite surface haptic display. Recently, Kim et al.[1] explored two-finger skin-slip haptic feedback to render the motion and thickness of virtual objects gripped between the thumb and index fingers. The authors explored the effect of visual-haptic congruency on skin-slip feedback perception.

Of the prior works about skin-slip haptic feedback in VR, the three earlier works[2–4] investigated skin-slip haptic feedback on the index finger only. In contrast, *SpinOcchio*[1] used a pair of spinning discs to implement a skin-slip feedback mechanism slim enough to accommodate both the thumb and index finger in a pinching grip. However, the prototype was still bulky and heavy for practical use, and users with small hands or short fingers would have difficulty holding the device as intended. As a result, *SpinOcchietto* was designed to address the issues of practical usability by having a smaller, lighter, and wearable form factor.

1.1 Overcoming Limitations of SpinOcchio

This work is an extension of *SpinOcchio*[1], specifically implementing the suggestions on simplification and miniaturization stated by the authors. As shown by the visual-haptic congruency experiment in the previous work, users of the prototype could not distinguish skin-slip feedback direction when haptic feedback was accompanied with visuals of virtual objects in VR. Taking into account the visual-haptic perception capability of the users, the pivoting mechanism of *SpinOcchio* was seen as ineffective for practical usage and was removed to simplify the working mechanism. Additionally, considering the handle of the device limits the usage of users with small hands or short fingers, the handle was removed to instead enable attaching the prototype directly to the fingers as a wearable haptic feedback device. With these modifications, the *SpinOcchietto* can accommodate a wide range of hand-sizes while alleviating fatigue due to large mass.

2 IMPLEMENTATION

The working principle of *SpinOcchietto* is similar to that of *SpinOcchio*[1] - a spinning disc in contact with the fingertip causes skin-slip haptic feedback, and the speed of the skin-slip feedback is mapped to the speed of virtual object movement. The distance between the discs is controlled by an actuator, and the resulting gap is mapped to virtual object width.

In detail, *SpinOcchietto* is composed of a pair of spinning discs, each with a radius of $25mm$, that are placed back to back and are gripped together using the thumb and index fingers. The prototype consists of three Dynamixel XL-330-M288[1] servo motors: two for actuating each disc at up to $95rpm$ and one for controlling the width between them in a range between $7-40mm$. Motor current can be read from the width-changing motor to estimate the user's grip pressure. The total mass of the prototype is $139g$ and is worn on the user's thumb and index fingers using velcro straps. The spinning disc, The VR application environments were developed in Unity[2]. The actuators were interfaced with Unity via the Dynamixel SDK C# library[3], and the baudrate was set at $4Mbps$. A VIVE Tracker 3.0[4] is worn on the back of the user's hand with a wrist strap to track the hand wearing *SpinOcchietto* in 3D space via a standard VIVE setup using SteamVR[5].

3 INTERACTIONS

The following types of interactions in VR are enabled through *SpinOcchietto* and are demonstrated in each virtual scene. User's hand position and grip pressure serve as primary input when interacting with virtual objects, and skin-slip speed, direction (bidirectional), and grip width change are the haptic outputs.

3.1 Molding a Virtual Object through Pinching

Using *SpinOcchietto*, the user is not limited to only passively feeling a virtual object slip between their fingertips but can also actively mold the object by squeezing their grip. This interaction is demonstrated through the Potter's Wheel scene, in which users can feel the spinning clay on the wheel with their fingertips. Additionally, applying pressure on the fingertips will deform the clay and make the part in contact narrower than the rest. Releasing fingertip pressure, the user can now feel the contour of the deformed clay of varying widths without making further deformations.

3.2 Holding, Pulling, and Releasing an Object

For ungrounded virtual objects, users can use *SpinOcchietto* to hold, lift or pull, and release them through controlling their grip strength. In the Fitness Center scene, the user can apply grip pressure to hold the pulley rope and move their arm to pull the weight off the ground. When the grip pressure is released, the user can experience the rope slip through their fingers as the weight falls back to the ground. Again, without applying grip pressure, the virtual rope can be felt slipping against the fingertips as the user moves their arms.

3.3 Materials of Different Elasticity

In addition to the interactions manipulating virtual objects, *SpinOcchietto* can simulate material of different properties. In the Material Lab scene, users are presented with three flasks each containing different materials. Beginning with the most rigid material on the left, the middle and right materials display increasingly elastic properties when pulled. Users can not only experience the material thinning at different rates when pulled but can also feel the different slipping rates of each material between the fingertips reflecting elastic materials such as rubber.

4 CONCLUSION

In this work, we presented *SpinOcchietto*, a wearable skin-slip haptic feedback device that was developed based on the suggestions for simplification and miniaturization stated by the authors of *SpinOcchio*[1]. Through the three VR applications presented, *SpinOcchietto* demonstrated the use of skin-slip feedback for VR interactions such as object molding, lifting, pulling, and releasing as well as experiencing virtual material with varying elastic properties. We hope our work serves as an inspiration for future works investigating the use of multiple digits or the whole hand for perceiving virtual object properties via skin-slip haptic feedback.

[1] https://emanual.robotis.com/docs/en/dxl/x/xl330-m288/
[2] https://unity.com/
[3] https://github.com/ROBOTIS-GIT/DynamixelSDK
[4] https://www.vive.com/us/accessory/tracker3/
[5] https://www.vive.com/us/support/vive/category_howto/setting-up-for-the-first-time.html

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2018R1A5A7025409).

REFERENCES

[1] Myung Jin Kim, Neung Ryu, Wooje Chang, Michel Pahud, Mike Sinclair, and Andrea Bianchi. 2022. SpinOcchio: Understanding Haptic-Visual Congruency of Skin-Slip in VR with a Dynamic Grip Controller. In *CHI Conference on Human Factors in Computing Systems*. 1–14.

[2] Jo-Yu Lo, Da-Yuan Huang, Chen-Kuo Sun, Chu-En Hou, and Bing-Yu Chen. 2018. RollingStone: Using single slip taxel for enhancing active finger exploration with a virtual reality controller. In *Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology*. 839–851.

[3] Victor Rodrigo Mercado, Maud Marchal, and Anatole Lécuyer. 2019. Entropia: towards infinite surface haptic displays in virtual reality using encountered-type rotating props. *IEEE transactions on visualization and computer graphics* (2019).

[4] Eric Whitmire, Hrvoje Benko, Christian Holz, Eyal Ofek, and Mike Sinclair. 2018. Haptic revolver: Touch, shear, texture, and shape rendering on a reconfigurable virtual reality controller. In *Proceedings of the 2018 CHI conference on human factors in computing systems*. 1–12.