Haptics in VR Using Origami-Augmented Drones

Difeng Yu* Weiwei Jiang* Andrew Irlitti Tilman Dingler Eduardo Velloso Jorge Goncalves Vassilis Kostakos

University of Melbourne, Australia

Abstract

Virtual reality (VR) aims to make the human-computer interaction experience more immersive. Without the sensation of force and proper haptic feedback, however, the illusion of presence often breaks when a user tries to touch a virtual object. We present a prototype that provides haptic feedback in VR using origami carried by a drone. The drone delivers origami to the user's hand when that user is about to touch a virtual object. The haptic experience can easily be modified by changing the origami to other shapes and paper types. Our work demonstrates a novel, customisable, and low-cost solution to enable VR haptics.

Keywords: Drone, encountered-type haptics, immersion, origami, paper folding, quadcopter, tactile feedback, virtual reality

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Human computer interaction (HCI)—Interaction devices—Haptic devices

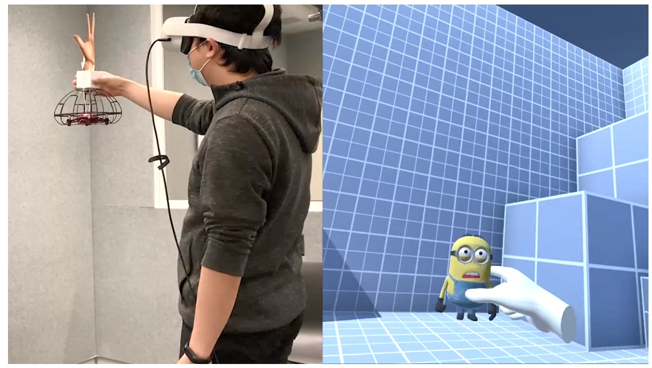


Figure 1: A demonstration of our prototype. A user grabs a minion inside the virtual space and, simultaneously, feels the haptic feedback provided by the origami carried by a drone in the physical world.

1 Introduction

Virtual reality (VR) technology allows users to be fully immersed in digital worlds, which enables new interaction experiences in product design, data analytics, and games. Without properly rendered haptic feedback, however, the illusion of presence can break when a user touches a virtual object. Previous works have attempted to address this issue through hand-held controllers or wearables [7], but they require users to carry additional devices, which may cause new problems such as impeding the motion of the user's hand. To overcome this challenge, we present a prototype that leverages origami carried by a drone as a low-cost solution to enable VR haptics.

Recent research has studied *encountered-type haptics* [4], where haptic devices autonomously position haptic proxies at the corresponding physical location of the virtual object. An intuitive method is enabling VR users to touch or interact with a replica of the virtual object in the physical world—for example, Suzuki *et al.* presented a room-scale solution by moving furniture with ground robots on the floor [9]. Alternatively, providing haptics with a drone may be more flexible in 3D VR space [2, 6]. More relevant to our work, Hoppe *et al.* proposed a method to simulate various VR interaction experiences by allowing users to touch, push, and grasp a drone [5]. Abtahi *et al.* enabled an even richer haptic interaction experience by rendering textures and animating passive props [1]. Moreover, Auda *et al.* equipped customized controllers on a drone which allows it to be used as an input device [3].

However, existing methods that leverage drones to provide VR haptics require sophisticated prototyping techniques, such as customized electronics or 3D printed models, for its haptic props. This makes the customization of the haptic experience somewhat challenging—users may have to 3D print new models to render objects with different shapes. We present a simple yet flexible way to generate haptics in VR using origami (*i.e.*, paper folding) carried by a drone. In our system, the drone delivers origami to the user's hand when they are about to touch a virtual object. Compared with existing systems, our solution does not require complex hardware design and can be deployed rapidly at a low cost: requiring only one or several pieces of paper with a holder to fix the origami on the drone. Users can also easily customize their haptic experience by modifying the origami to other shapes and paper types. Our demo, therefore, shows a novel, customizable, and low-cost solution to enable VR haptics that could inspire relevant applications.

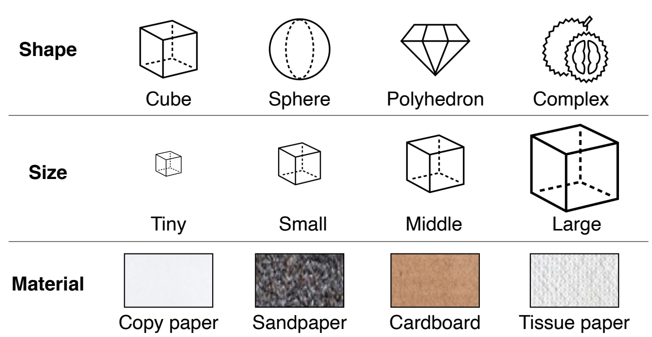
*Both authors contributed equally to this research.

2 Prototype

In this demo, we will present a prototype of origami-augmented drones to provide haptic feedback in VR.

2.1 Design Space

The origami can be designed based on the following design space to enable various types of haptic feedback.



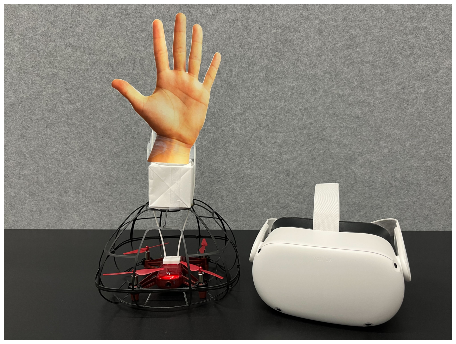


Figure 2: The equipment that will be used in the demo: a RoboMaster Tello Talent micro-drone and an Oculus Quest 2 headset.

2.2 Interaction Scenarios

We developed a virtual environment to demonstrate various haptic feedback techniques supported by our prototype, including object shapes and textures using different origami objects. In particular, we will focus on the following interaction scenarios:

- **Scenario 1 - Grasping**: users can see a virtual minion in VR. Their goal is to grasp the minion to feel the shape of the minion.
- **Scenario 2 - Textures**: users can see a virtual cat and a virtual hedgehog in VR. By touching different faces of the origami shape (*i.e.*, fur or sandpaper), they can experience different haptic feedback (*i.e.*, smooth and spiky) when touching different animals.
- **Scenario 3 - High-five**: users can see a virtual character in VR. They can perform a high-five with the character. The origami hand serves as an example of complex shapes.

2.3 Implementation

Hardware: We will use a RoboMaster Tello Talent micro-drone and an Oculus Quest 2 headset for the demo (see Figure 2). The drone is encompassed by a plastic net to avoid collisions. The origami used for providing haptics is mounted on top of the drone. Above the origami, a printed paper hand is attached as an anchor to track the position of the drone in the Oculus Quest 2 headset. This is a low-cost solution for tracking the position of the drone without external cameras, as Oculus Quest 2 does not allow accessing the raw camera feed data. Both the origami and the paper hand are fixed by 3D printed poles.

Software: We developed our virtual environment and the control system in Unity C#. The headset tracks the drone's position in real-time, and then renders the virtual object at the drone's position. The drone is controlled programmatically using its python API. In the meantime, the users' hand is also tracked and rendered while interacting with the virtual object (*e.g.*, grasping).

3 Demo Presentation

3.1 Space and setup

We will present our demo in a $3m \times 3m$ area. Each session will last up to 5 minutes with one of the selected audience. The selected audience will wear an Oculus Quest 2 headset, while other audience will observe the interaction experience from the outside. Our micro-drone will fly within the demo area during the session. The whole session will be monitored by at least one of our presenters.

3.2 Safety

Ensuring safety in our demonstration is our primary concern. While the propellers of the lower-power micro-drone are made of plastic, to further protect the safety of the users, we will encapsulate the drone with a dense net that prevents fingers from reaching the rotors [1]. Additionally, we will set boundaries around our demo area with temporary walls (such as using self-standing posterboards). An alternative presentation form is that our presenter will demonstrate all the interaction scenarios, while the audience will only observe the presenter's performance and watch the streamed VR experience from a TV screen.

4 Conclusion and Future Work

We present a prototype that leverages origami-augmented drones to provide haptic feedback in VR. Our solution can inspire ISMAR audiences including VR researchers, designers, developers for new applications. Our solution can be extended future applications like embedding paper-based soft robot for more complex touch sensation [8], using multiple drones for target representation, and allowing throwing experiences in VR [10], which can foster interesting discussions at the conference.

References

[1] P. Abtahi, B. Landry, J. J. Yang, M. Pavone, S. Follmer, and J. A. Landay. Beyond the force: Using quadcopters to appropriate objects and the environment for haptics in virtual reality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, p. 1–13. Association for Computing Machinery, New York, NY, USA, 2019. doi: 10.1145/3290605.3300589

[2] P. Abtahi, D. Y. Zhao, J. L. E., and J. A. Landay. Drone near me: Exploring touch-based human-drone interaction. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.*, 1(3), sep 2017. doi: 10.1145/3130899

[3] J. Auda, N. Verheyen, S. Mayer, and S. Schneegass. Flyables: Haptic input devices for virtual reality using quadcopters. In *Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology*, VRST '21. Association for Computing Machinery, New York, NY, USA, 2021. doi: 10.1145/3489849.3489855

[4] E. J. Gonzalez, P. Abtahi, and S. Follmer. Reach+ extending the reachability of encountered-type haptics devices through dynamic redirection in vr. In *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology*, pp. 236–248, 2020. doi: doi.org/10.1145/3379337.3415870

[5] M. Hoppe, P. Knierim, T. Kosch, M. Funk, L. Futami, S. Schneegass, N. Henze, A. Schmidt, and T. Machulla. Vrhapticdrones: Providing haptics in virtual reality through quadcopters. In *Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia*, MUM 2018, p. 7–18. Association for Computing Machinery, New York, NY, USA, 2018. doi: 10.1145/3282894.3282898

[6] P. Knierim, T. Kosch, V. Schwind, M. Funk, F. Kiss, S. Schneegass, and N. Henze. Tactile drones-providing immersive tactile feedback in virtual reality through quadcopters. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pp. 433–436, 2017. doi: 10.1145/3027063.3050426

[7] P. Lopes, S. You, L.-P. Cheng, S. Marwecki, and P. Baudisch. Providing haptics to walls and other heavy objects in virtual reality by means of electrical muscle stimulation. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, CHI '17, p. 1471–1482. Association for Computing Machinery, New York, NY, USA, 2017. doi: 10.1145/3025453.3025600

[8] S. Mintchev, M. Salerno, A. Cherpillod, S. Scaduto, and J. Paik. A portable three-degrees-of-freedom force feedback origami robot for human–robot interactions. *Nature Machine Intelligence*, 1(12):584–593, 2019. doi: 10.1038/s42256-019-0125-1

[9] R. Suzuki, H. Hedayati, C. Zheng, J. L. Bohn, D. Szafir, E. Y.-L. Do, M. D. Gross, and D. Leithinger. Roomshift: Room-scale dynamic haptics for vr with furniture-moving swarm robots. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, CHI '20, p. 1–11. Association for Computing Machinery, New York, NY, USA, 2020. doi: 10.1145/3313831.3376523

[10] T. Zindulka, M. Bachynskyi, and J. Müller. Performance and experience of throwing in virtual reality. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, CHI '20, p. 1–8. Association for Computing Machinery, New York, NY, USA, 2020. doi: 10.1145/3313831.3376639