VR Sword Fighting with a Handheld Multi-Directional Impact Feedback Device

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Figure 1: Multi-directional impact feedback generated by the proposed device. (a) Device motion during rearward impact feedback. (b) Device motion during rear-left impact feedback. (c) Five impact directions supported by the proposed device.

Abstract

We present a VR sword-fighting system using a handheld device that generates impact feedback in five directions based on the direction of the sword swing. The device combines four fixed flywheel-based impact units. Activating them individually or in combination produces impacts in five directions: left, rear-left, rear, rear-right, and right. Each pair of opposing flywheels is arranged coaxially, with their angular-momentum vectors pointing in opposite directions, to reduce gyroscopic effects. Participants wield the device as a virtual sword and experience direction-dependent impacts while playing an action game against virtual enemies.

CCS Concepts

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

Keywords

virtual reality, haptics, impact feedback, handheld device, flywheel

ACM Reference Format:
Kazuki Hara, Issa Ueno, Aoi Kato, Zhaoyang Yuan, Yuya Maekawa, Fumihiko Nakamura, Asako Kimura, and Fumihisa Shibata. 2026. VR Sword Fighting with a Handheld Multi-Directional Impact Feedback Device. In *32nd ACM Symposium on Virtual Reality Software and Technology (VRST '26), November 16–18, 2026, Sendai, Japan.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3822517.3849969

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VRST '26, Sendai, Japan
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ACM ISBN 979-8-4007-2811-2/2026/11
https://doi.org/10.1145/3822517.3849969

1 Introduction

Impact feedback is effective for conveying contact with virtual objects in VR [2], and handheld devices are particularly suitable for applications that require a wide range of user motion. Previous studies have generated transient force or torque feedback by changing the angular momentum of flywheels [2, 4]. A gimbal-based mechanism that changes the orientation of a flywheel has also been proposed for multi-directional haptic feedback [1], while a dual-flywheel system has been developed to provide single-axis moment pulses [3]. However, fixed configurations that provide multi-directional impact feedback while reducing gyroscopic effects remain underexplored.

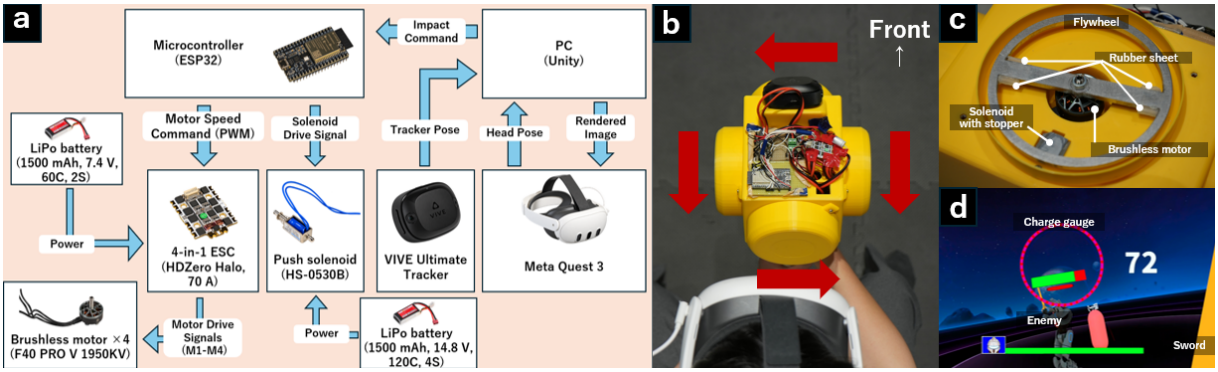


Figure 2: Overview of our system. (a) System architecture and data flow. (b) Basic impact directions generated by the four impact units. (c) Flywheel-based impact-generation unit. (d) VR sword-fighting application. Third-party assets visible in (d): *Halo Lightsaber* by rm8080w, *Sci-Fi Cosmos Sky Dome* by EA Experience Lab Art, and *Alien Robot 4* by MB Marcelo Barrio. These assets are used under the Standard Unity Asset Store EULA (Single Entity).

In this study, we developed a handheld device with four fixed flywheel-based impact units that generate impacts in five directions through individual or combined activation (Figure 1). Each pair of opposing flywheels is arranged coaxially, with their angular-momentum vectors pointing in opposite directions, to reduce gyroscopic effects. The device is integrated into a VR sword-fighting application that provides impact feedback according to the detected swing direction.

2 Multi-Directional Impact Feedback Device

2.1 Device Configuration

We developed a handheld impact feedback device designed for two-handed use in VR sword fighting. Four impact units are positioned at the front, rear, left, and right of the housing. Each unit comprises a brushless motor, a stainless-steel flywheel (100 mm in diameter, 72 g), a stopper, and a push solenoid (Figure 2c).

An ESP32 controls the four brushless motors through a 4-in-1 ESC and drives the push solenoids. A VIVE Ultimate Tracker tracks the device's position and orientation. The device is powered by external LiPo batteries (Figure 2a). The device weighs approximately 1.8 kg. Protective covers, rounded housing edges, and an anti-slip grip improve safety.

2.2 Five-Directional Impact Generation

Each impact unit uses a flywheel–stopper collision mechanism based on SpinShot [2]. Each flywheel rotates counterclockwise when viewed from the outside of the device. A push solenoid moves the stopper into the path of the rotating flywheel, rapidly changing its angular momentum and producing a transient impact. A rubber sheet is attached to the contact surface to reduce mechanical damage and noise.

The stopper position determines the impact direction of each unit. The front unit generates leftward feedback, the rear unit rightward feedback, and the two side units rearward feedback (Figure 2b). Consequently, activating the front unit, rear unit, both side units, the front unit with both side units, or the rear unit with both side units generates left, right, rear, rear-left, and rear-right impacts, respectively (Figure 1c). This combination-based design enables five-directional impact feedback while keeping all four impact units in fixed orientations.

2.3 Design for Reducing the Gyroscopic Effect

Changing the orientation of a rotating flywheel generates gyroscopic torque, which can resist manipulation of the handheld device. To reduce this effect, the front–rear and left–right flywheel pairs are arranged symmetrically and coaxially, with the angular-momentum vectors of opposing flywheels pointing in opposite directions.

For the two side units, the angular-momentum vectors must point in opposite directions while both units generate rearward impact feedback. Therefore, the left unit is mounted in the opposite fore–aft orientation from the right unit, with its stopper positioned above the flywheel. This arrangement is intended to reduce net gyroscopic torque and the resulting resistance during device manipulation while preserving the impact directions required for five-directional feedback.

3 VR Sword-Fighting Application

We developed a VR sword-fighting application in Unity for a Meta Quest 3 connected via Steam Link. Seated participants wield the device as a virtual sword and control avatar movement by slightly leaning their upper body in the desired direction.

A charge gauge manages the interval required for motor spin-up and mechanical recovery. When the gauge is full, the motors begin rotating and the next attack becomes available (Figure 2d).

Unity receives the device pose from the VIVE Ultimate Tracker and head-tracking data from the Meta Quest 3. Upon contact with an opponent, Unity classifies the sword swing into one of five directions from its velocity vector and sends the corresponding command to the ESP32, which actuates the required solenoids to generate the selected impact (Figure 2a). Approximately 300 ms later, the stoppers return to their initial positions and the charge gauge resets. This interaction links the detected swing direction to the corresponding physical impact during sword contact.

Future work will evaluate impact-direction discriminability and gyroscopic-effect reduction.

References

[1] Jose Luis Berna Moya, Anke van Oosterhout, Mark T. Marshall, and Diego Martinez Plasencia. 2024. HapticWhirl, a Flywheel-Gimbal Handheld Haptic Controller for Exploring Multimodal Haptic Feedback. *Sensors* 24, 3 (2024), 935. doi:10.3390/s24030935

[2] Chia-An Fan, En-Huei Wu, Chia-Yu Cheng, Yu-Cheng Chang, Alvaro Lopez, Yu Chen, Chia-Chen Chi, Yi-Sheng Chan, Ching-Yi Tsai, and Mike Y. Chen. 2024. SpinShot: Optimizing Both Physical and Perceived Force Feedback of Flywheel-Based, Directional Impact Handheld Devices. In *Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology* (Pittsburgh, PA, USA) *(UIST '24)*. Association for Computing Machinery, New York, NY, USA, Article 138, 15 pages. doi:10.1145/3654777.3676433

[3] Julie M. Walker, Michael Raitor, Alex Mallery, Heather Culbertson, Philipp Stolka, and Allison M. Okamura. 2016. A dual-flywheel ungrounded haptic feedback system provides single-axis moment pulses for clear direction signals. In *2016 IEEE Haptics Symposium (HAPTICS)*. 7–13.

[4] Willa Yunqi Yang, Yifan Zou, Jingle Huang, Raouf Abujaber, and Ken Nakagaki. 2024. TorqueCapsules: Fully-Encapsulated Flywheel Actuation Modules for Designing and Prototyping Movement-Based and Kinesthetic Interaction. In *Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology* (Pittsburgh, PA, USA) *(UIST '24)*. Association for Computing Machinery, New York, NY, USA, Article 98, 15 pages. doi:10.1145/3654777.3676364