# Electromagnetically Modulated Resistance Mechanism for Passive Force-Feedback Devices

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***Abstract*—This study presents a novel electromagnetically modulated resistance mechanism for compact and efficient passive force feedback in wearable devices. Two electromagnets dynamically modulate the tension of the tendon to generate resistive forces without bulky hardware or complex control. A wearable haptic device for the index finger and thumb was built to validate the mechanism. A user study with nine participants evaluated stiffness perception in three tasks (10 trials each): index-only, thumb-only, and pinch. Participants comfortably distinguished stiffness levels using resistive feedback, demonstrating the potential of the device to deliver lightweight, compact, and effective passive haptics in virtual and remote interaction scenarios.**

***Index Terms*—Electromagnet, Haptics, Passive Device, Resistance Force Feedback, Wearable Device**

## I. Introduction

Passive force feedback devices are well-suited for wearable haptics, rehabilitation, and teleoperation, where portability and reliability are essential. However, many systems still rely on high voltage supplies, bulky actuators, or thermal elements, leading to activation delays and limited wearability [1]. This work presents a compact wearable device that uses a novel electromagnetically modulated resistance mechanism. The approach enables controlled stiffness feedback while reducing system complexity, power use, and improving user experience.

## II. Proposed Haptic Mechanism and Device Design

The proposed mechanism employs two custom-designed electromagnets to modulate the tension of the tendon by compressing a slider from opposite sides, generating friction resistance or fully locking the movement to produce passive force feedback. The attractive force between the electromagnets is controlled by the supplied current: When no current is applied, the slider moves freely, resulting in no feedback; when current is applied, opposing polarity induces magnetic attraction, compressing the slider and increasing resistance proportional to the current. This friction-based modulation enables precise control of tendon tension, enhancing force feedback fidelity and allowing users to perceive varying stiffness levels. A wearable haptic device was implemented based on this mechanism (Fig. 1), featuring a soft silicone body for comfort, fingertip caps connected to tendons, and elastic straps for a secure fit and a total weight of 138 g. Two dorsal haptic units, each with two electromagnets (15.4 mm × 15.5 mm), compress a friction slider (3D-printed with four Kevlar threads) to regulate tendon tension and resist finger motion.

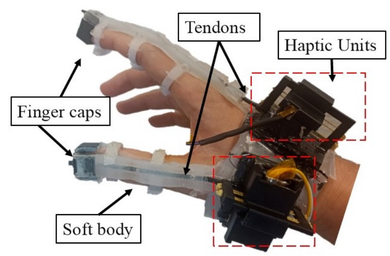


Fig. 1. Wearable passive force feedback device.

A user study evaluated the performance of the wearable haptic device in a stiffness discrimination task. Participants interacted with virtual objects, where contact triggered electromagnet activation and generated passive resistance. Three separate tasks were conducted using the index finger, thumb, and pinch gesture to identify the stiffer virtual surface. The results demonstrated the device's comfort, responsiveness, and effectiveness in conveying stiffness variations.

## III. Demonstrations

During the hands-on demonstration, participants will be seated and equipped with a Meta Quest 2 headset and the wearable haptic device on their right hand, which covers the thumb and index fingers. The haptic device is powered by a DC power supply and controlled via a Unity application running on a laptop, with the visual output mirrored to an external monitor for observers. Participants will perform three stiffness discrimination tasks. In the first task, they will use the index finger to compare the stiffness of two virtual surfaces. In the second, they will repeat the task using the thumb. The third task involves a pinch gesture to evaluate which of two virtual cubes offers greater resistance. An additional chair is allocated for the author, who will assist participants during the demonstration, explain the underlying mechanism, and respond to questions. A supporting poster will provide an overview of the system architecture, control strategy, and user study results.

## References

[1] R. Thilakarathna and M. Phlernjai, "Design and development of a lightweight, low-cost cylindrical electrostatic clutch," *Engineering Science and Technology, an International Journal*, vol. 49, p. 101600, 2024.