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# WRIST: A Wearable Radial Interface for Sensory hapTic feedback

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*Abstract*— **Despite the critical role of haptic feedback in virtual and augmented reality (VR/AR), existing wearable haptic devices offer only a single vibratory modality or depend on bulky external hardware that undermines portability and accessibility. To address this gap, we present WRIST (Wearable Radial Interface for Sensory hapTic feedback), a low-cost ($500), 3D-printed multisensory haptic bracelet integrating radial squeeze and vibrotactile feedback via a single DC motor and five linear resonant actuators. Assembled using standard hand tools and off-the-shelf electronics, WRIST delivers a peak squeeze force of 14.6 N and ramps from 0 to 10 N within 0.1 s. Compared to existing related works, WRIST matches state-of-the-art performance while reducing costs by over 80% and eliminating external power and signal generators. Its modular design supports rapid assembly and repair for use in VR/AR training, teleoperation, rehabilitation, and entertainment, paving the way for broader adoption of wearable haptic devices in physical and virtual environments.**

## I. INTRODUCTION

Haptic feedback is critical for intuitive user-object interactions in virtual and augmented reality (VR/AR) environments [1], [2]. By engaging the sense of touch, haptic cues enable users to perceive contact forces, textures, and object properties more intuitively.

Various wearable mechanisms have been designed to render haptic feedback via cutaneous modalities such as skin stretch, pressure, squeeze, and vibration [3]. Most current wearable haptic devices use a single feedback mode – typically vibration – due to the low cost of implementation and low power consumption [4]. Multi-modal systems deliver cues via separate modules and control paths [5] or consolidate them under a unified architecture [6], [7]. Furthermore, some groups have produced lightweight wireless multisensory bracelets [6], which typically trade off feedback strength and user comfort. Most designs still depend on costly custom components and bulky external hardware that limits accessibility and user mobility [7].

We present WRIST (Wearable Radial Interface for Sensory hapTic feedback), a haptic bracelet combining multi-modal squeeze and vibrotactile feedback into a compact design. Our device advances the state of the art by integrating multisensory haptic feedback in a low-cost (under $500) platform, prioritizing reproducibility via 3D-printed and off-the-shelf components while matching the performance of more complex systems such as the Tasbi [7].

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## II. SYSTEM AND STRUCTURE

WRIST comprises two core subsystems, radial squeeze and addressable vibration feedback, coordinated via a single custom printed circuit board (PCB) (Fig. 1b). A VR event (e.g., button press) is serialized and sent over USB-C (USB 2.0 data + USB-Power Delivery up to 9V at 3A) to the onboard microcontroller (MCU) STM32G0B1RET6, which parses the command, drives the DC motor through an H-bridge for squeeze control, and dispatches $I^2C$ packets to the five LRA modules. All electromechanical parts are housed in PLA enclosures and linked by a 60A-shore TPU band (fits 18–23 cm wrists) with embedded wiring.

### A. Radial Squeeze

The radial squeeze subsystem employs a custom Maxon DC motor (DCX12L EB KL 9V) coupled to an aluminum spool to impose uniform pressure around the wrist. A 40 lb strength braided line is anchored to the spool and routed around low-friction metal dowels within the motor housing and over each vibrotactor module. As the motor rotates, the line winds onto the spool, decreasing the effective circumference of the TPU band and generating uniform radial squeeze force. The machined spool geometry ensures an even winding and symmetric force distribution across all dowels. This actuation is similar to that of the Tasbi with modified dowel placement for modularity [7].

The DC motor is controlled via a Texas Instruments DRV8871 H-bridge that delivers PWM-regulated current. An incremental encoder on the motor shaft implements a two-phase calibration at startup: during the "tighten" phase, the motor winds the line while monitoring encoder tick rate; once the per-step angular increment falls below a threshold, signaling rising back-torque, the system records that as the fully tightened limit. The "loosen" phase then unwinds the line by a preset angular offset to reach zero tension, establishing the user-specific base tightness. These encoder-based end stops tailor the available spool travel to each wearer's wrist size, ensuring consistent, repeatable squeeze amplitudes across users.

### B. Addressable Vibration

Vibrotactile feedback is delivered by five LRAs (Vybronics VG1040003D), selected for their production of the highest vibration energy of any coin-shaped LRA. Each LRA module mounts on a custom 15.2 x 28.4mm PCB housing a Renesas DA7281 haptic driver, enabling digital frequency and amplitude control. The MCU communicates with five DA7281 chips at Fast-Mode-Plus (1 MHz) across two $I^2C$

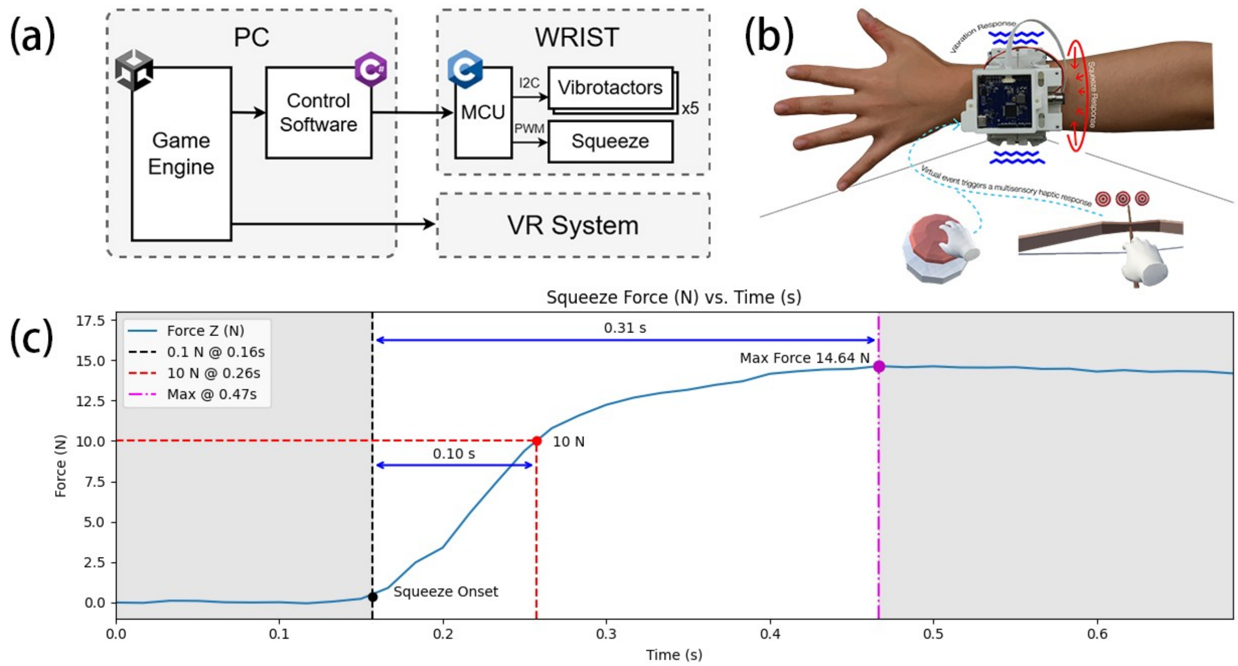


Fig. 1. WRIST workflow, device picture, and test results. (a) End-to-end WRIST system pipeline: PC control software processes virtual events in the game engine, which commands the wearable's MCU via $I^2C$ and PWM to drive five vibrotactors and motor actuation; (b) Figure of device being worn by a subject - virtual events such as button press and bow-arrow interactions will deliver squeeze and vibration; (c) Test result of squeeze force measured with ATI Nano 25 Sensor. The device reached 10N in a span of 0.1 s and reached a maximum force of 14.64 N in 0.31 s.

channels. Amplitude is specified as an 8-bit value (0–255) and updated in real-time by the MCU, which sequences amplitude and timing to generate custom haptic envelopes. Vibration patterns can be synchronized with the radial squeeze subsystem or driven independently, enabling multi-modal feedback simultaneously.

## III. Testing and Results

To evaluate the WRIST's squeeze performance, we built a testbench inspired by Tasbi's rig [7], featuring an Ecoflex™ 00-30 silicone sleeve—chosen for its skin-like elasticity—molded over a ProJet® MJP 2500–printed rigid inner shell to emulate underlying bone. An ATI Nano25 six-axis force sensor embedded in the shell feeds a 16-bit Quanser USB-8 DAQ for precise measurements. Post-processed data show the WRIST delivers 10 N in 0.1 s and 14.64 N in 0.31 s (Fig. 1c).

## IV. Conclusions and Future Work

WRIST is a wearable, multi-modal haptic bracelet that delivers vibrotactile and radial squeeze feedback to enhance immersion and performance in VR/AR applications. By combining a single custom DC motor with encoder-based calibration and five digitally driven LRAs on a unified PCB, WRIST achieves multi-modal haptic feedback with a low-cost, compact, and modular design. Its 3D-printed, modular design simplifies assembly and maintenance, and fully integrated electronics simplify device setup and operation.

Future work will extend the central PCB with a precision current-sense resistor on the motor supply rail, enabling continuous monitoring of motor torque via current draw. In parallel, we will integrate a SingleTact capacitive force sensor into the squeeze loop, providing a standalone, sensor-driven closed-loop control scheme as an alternative to the current encoder-based calibration. These enhancements improve force accuracy, safety, and adaptability across a wider range of users and applications.

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