Design for Wrist-Worn Haptic Device with Custom Voice Coil Actuation

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***Abstract*— In this paper, we propose a wrist-worn device with custom voice coil actuation to provide haptic feedback on the wrist while allowing participants to use their hands in real-world interactions. The custom voice coil is designed with a magnet and a strip of wires rolled around a cylinder. The intensity and frequency of the rendered feedback can be adjusted by design parameters, such as wire width, coil height, coil diameter, and the chosen magnet power. The proposed haptic device can be triggered effectively by users' interactions in virtual environments.**

I. Introduction

Haptic feedback is critical to increasing the realism of interactions in virtual reality (VR) and augmented reality (AR) environments. Even though most devices render haptic feedback on users' fingertips, haptic relocation has also been shown to be effective in allowing for believable interactions and effective discrimination performances between different interaction conditions [1]. Such haptic relocation offers haptic information to the users without limiting the interaction capabilities with real objects and environments, which might be problematic, especially during AR applications.

Current haptic devices mostly utilize rigid DC actuators [2] or voice coils [3]. Such off-the-shelf actuators struggle with the trade-off between rendered forces/displacements, size, and cost. In this paper, we propose a wrist-worn haptic device based on a custom-made voice coil actuator – allowing us to adjust the overall size and achieve higher-intensity feedback as needed.

II. Custom Voice Coil-Based Haptic Device

We propose a custom voice coil-based device in Fig. 1 with three main parts: a voice coil actuator, a wearable base, and an electronic setup. We designed the voice coil using four neodymium magnets and 0.25 millimeters copper wire to be wrapped around a cylinder with 20 millimeters in height and 35 millimeters in diameter. These parameters are decided to obtain the most effective feedback intensity without limiting its wearability. The voice coil and magnets are placed on a 3D-printed base. A satin fabric material is chosen between the movable tactor and the user's skin to minimize the material dissipation and maximize their comfort.

In the electronics part, a Raspberry Pi Pico microcontroller and L293B motor driver are used. A voltage regulator gives stable voltage to the device, and a current sensor measures the current to prevent the motor driver from exceeding the maximum output current capacity. Ultimately, the proposed haptic wrist-worn device works with a 10 V supply – which creates approximately 700-900 mA to pass through the voice coil safely. The device can move at 1-40 Hz, which could potentially render interaction forces up to 1.5 N (as measured by a Force Sensing Resistor (FSR)). Finally, USB to TTL UART converter communicates the controller unit with the computer to receive trigger commands from the Unity3D environment for AR/VR applications.

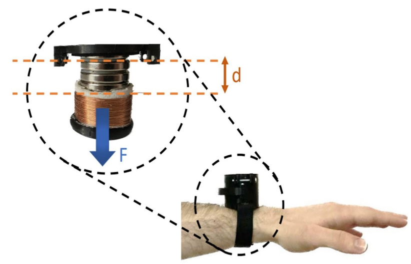

Fig. 1. Voice-coil based wrist-worn haptics: when actuated, the magnet moves the coil with a displacement d and renders forces F on user's skin.

III. Discussion and Future Work

In this paper, we presented the design of our low-cost, custom-made voice coil-based wrist-worn haptic device. Based on our preliminary tests, the device can render noticeable feedback with different intensities (50% - 100% of the duty cycle) and different operational frequencies (1 - 40 Hz).

We will integrate the proposed device with different virtual environments based on manipulation, exploration, and training virtual tasks. We will also analyze the device's efficiency and compare the performance capabilities with other haptic devices based on different actuator technologies or body locations. In addition, we will develop algorithms to map virtual feedback on the wrist and integrate this device into various exploration/guidance applications in the VR/AR environment.

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