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High-Fidelity Apparent Motion with Conformal Wearable Haptics

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I. INTRODUCTION

Virtual and augmented reality (VR/AR) have driven a growing need for wearable haptic devices [1], which in turn must overcome size, weight, and power constraints. One promising workaround is to exploit tactile illusions [2], such as the apparent motion [3], where a continuous sensation of movement is evoked on the skin by stimulating only a series of discrete points. This effect has been widely demonstrated on the palm, wrist, forearm, and even between hands.

While previous studies have explored factors such as actuation type [4] and speed [5], they have largely overlooked the fidelity of the motion sensation itself. Most systems use up to five actuators spaced at least $\sim 30\,\mathrm{mm}$ apart (on the same order as the wavelength of shear waves in skin), thus making truly smooth motion percepts unachievable.

In this demonstration, we introduce a conformable haptic interface featuring a dense 1D array of miniature electromagnetic linear resonant actuators (LRAs). Designed to meet somatosensory criteria, it elicits high-fidelity apparent motion illusions to users. This device not only advances the field of wearable haptics but also enables foundational research into the spatiotemporal limits of tactile motion perception.

II. DEMONSTRATION DESCRIPTION

A. Materials

Our device features a 1D array of 24 unit cells with a 7 mm pitch, as shown in Fig. 1.A. Each cell combines an off-the-shelf linear resonant actuator (VG0640001D, Vybronics) and a 3-axis accelerometer (ADXL350, Analog Devices) for full-field vibrometry of cutaneous waves. The LRAs are driven sequentially by a 230 Hz sine input, delivering $12\,\mathrm{m{\cdot}s^{-2}}$ of normal acceleration to the skin. Components are mounted on a highly-flexible, 100 µm-thick polyimide substrate and encapsulated in silicone (Sylgard 184, Dow Corning). For the demonstration, the device will be temporarily affixed to the skin with medical-grade adhesive (safe and quick to remove) and, while currently USB-powered, will be battery-powered and untethered for the live experience. Its low mass (34 g) and snug fit (Fig. 1.B.) further enhance haptic fidelity.

B. Protocol

The demonstration lasts about 10 min, during which participants wear the device either wrapped around their forearm or placed longitudinally, as in Fig. 1.B. When wrapped in a loop, it delivers continuous apparent motion. One or more pulses travel clockwise or counterclockwise to demonstrate directional cues for navigation (see Fig. 1.C). The dense array and swift embedded commutation enable faithful feedback at speeds up to $\sim 0.5\,\mathrm{m{\cdot}s^{-1}}$, surpassing both existing devices and human gestures, thus offering a broad set of haptic sensations. Alternatively, placing the device along the forearm better induces motion resembling the natural cues found in touch communication and interpersonal touch [6]. A second, unpowered unit is handed to attendees awaiting their turn.

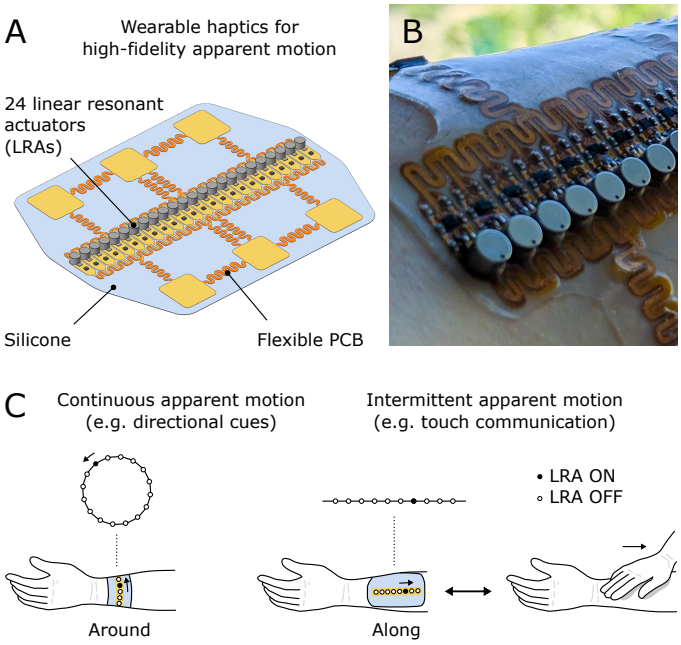

Fig. 1. A) Schematic of the wearable haptic interface. B) Device conformally mounted on skin using medical-grade adhesive. C) Example configurations for producing high-fidelity illusions of apparent motion on the forearm.

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