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Demonstration: A surface-haptic touchpad that actively guide user fingers on rich interfaces

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***Abstract*—Rich haptic feedback on touch surfaces such as touchscreens and touchpads would restore procedural memory and dramatically improve interaction by tactually guiding users to relevant targets. Unfortunately, surface haptics and vibrotactile actuators cannot provide the feedback necessary to push and pull users around the interface. We demonstrate the flatLoop, a low-profile active tactile device that provides active force feedback. Because the flatLoop actively deforms the fingertip, it can create compelling tactile illusions such as virtual buttons, knobs, and realistic elastic and viscous environments. Moreover, because it actively pushes and pulls users to specified locations, it can assist them in their search for content, such as guiding them to specific keys. We showcase several interactive examples of common UI elements: an introductory menu with directional tactile cues when swiping left or right; a drum machine with the sensation of a rotary knob, toggle switch, and a 2D button board; a number game with tactile guidance rendered as potential wells; and a Line Following feature where users can be guided through a curved tunnel. By showcasing tangible interactions with familiar UI elements, this demo aims to inspire broader interaction designs and encourage the integration of active tactile feedback into next-generation touch interfaces.**

I. Introduction

Surface haptics allows users to feel textures and shapes on flat surfaces. These technologies typically rely on friction modulation, which is passive and only works on sliding fingers [1], [2], [3]. This restriction leads to the ineffectiveness of guidance for slow-moving or static fingers. Recent advancements in surface haptics can guide static fingers by pushing and pulling users' fingers toward targets using modulated active lateral forces [4], [5], [6], [7]. Our demonstration is based on our recently developed device, the flatLoop [8], which generates net lateral forces on a touchpad through ultrasonic traveling waves. Unlike previous active surface haptic devices, like those relying on asymmetric friction [6], which is complex in control and hardware, and that using traveling waves [7], which has bulky form factors unsuitable for consumer devices, our flatLoop has a low-profile design (5 mm in height), making it compatible with everyday touch interfaces. The system can dynamically guide users' fingertips by simulating potential wells, buttons, and other UI elements.

To our knowledge, this is the first interactive demonstration of a low-profile active surface haptic device that supports rich touch interactions. The compact design demonstrates the feasibility of embedding active haptics in a wide range of practical applications, including consumer electronics, interactive public displays, classroom tools, and vending machines.

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Fig. 1. The flatLoop device provides rich tactile feedback using active force across various user interfaces.

II. System overview and interactions

The demonstration setup consists of an ultrasonic ring-shaped actuator (the flatLoop), an optical position sensor, an external display, control and amplification circuitry, and a host computer that communicates with the microcontroller (Fig. 1). An infrared sensor (Neonode, NNAMC1580PCEV) tracks the user's finger position at 200 Hz. Two synchronized ultrasonic signals are generated using direct digital synthesis (AD9834, Analog Devices) circuits and amplified by transformer-based circuits. A microcontroller (Adafruit Feather M4 Express, Adafruit Industries) modulates the amplitude and phase of the ultrasonic signals based on finger position, creating active force fields.

This demonstration highlights a variety of touch interaction scenarios enhanced by active haptic feedback. Participants will experience:

- **Introductory Menu:** Directional tactile cues guide users as they swipe left or right across the interface.
- **Drum Machine:** Haptic sensations emulate a rotary knob, toggle switch, and a 2D button board.
- **Number Game:** Virtual potential wells provide guidance toward targets with a number.
- **Line Following:** Users are tactually guided along a virtual curved path.

All interactions are performed with bare fingers. These examples demonstrate how active surface haptics can enrich user experience and improve accessibility in future touch-based interfaces.

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