Demo of FlowRing: Seamless Cross-Surface Interaction via Opto-Acoustic Ring

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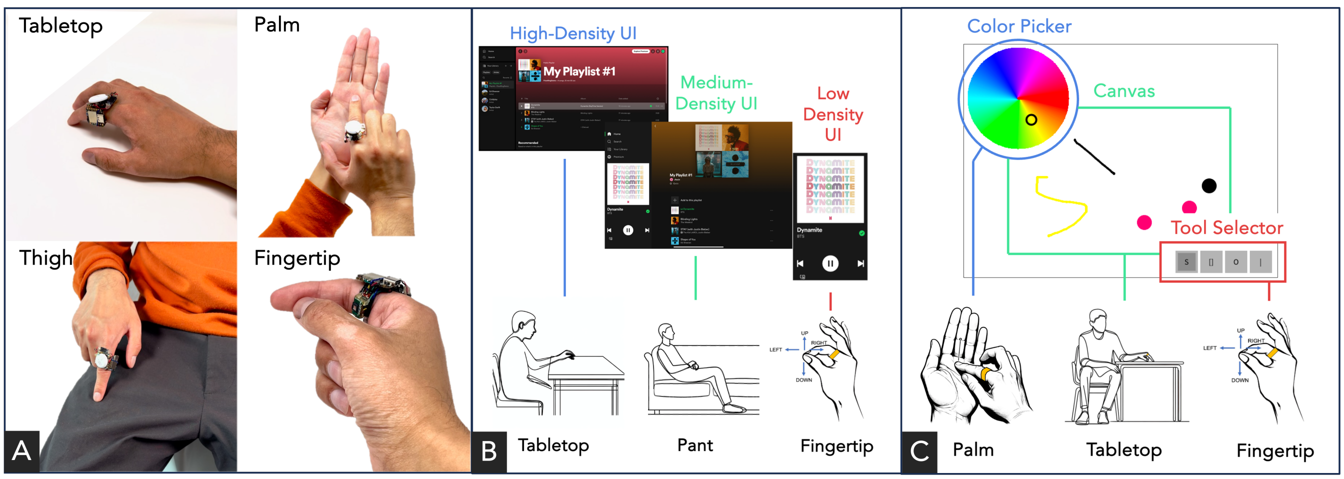

Figure 1: (A) FlowRing allows for precise on-surface interactions on commonly accessible surfaces and quick in-air microgestures. (B) FlowRing provides seamless input by adjusting the UI density based on user posture and surface, offering high-density for desktop use, medium-density for couch use, and low-density for mobile use. (C) UI elements can be mapped to surfaces with FlowRing, allowing color selection on the palm, canvas manipulation via tabletop swipes, and tool selection with fingertip microgestures.

ABSTRACT

We demonstrate FlowRing, a ring-form-factor input device that enables interaction across a range of ad-hoc surfaces including desks, pants, palms and fingertips with seamless switching between them. This versatility supports systems that require both high precision as well as mobile control, such as mobile XR. FlowRing consists of a miniature optical flow sensor, skin-contact microphone, and IMU, providing a unique ergonomic design that rests at the base of the finger like conventional jewelry. We show the potential of FlowRing to enable precise control of interfaces on available surfaces via music player application and whiteboarding application.

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CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; **Interaction techniques**.

KEYWORDS

Input technology, 2D tracking, microgestures detection, ring

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1 INTRODUCTION

Surface-based interaction is the primary input modality because of its ergonomic, precise, and self-haptic characteristics [2, 4]. However, most surface-based interactions only support operating a device on a single surface [1, 3]. For example, people use a mouse to operate a computer on the desktop and use a touch screen to operate mobile phones or tablets. In the future, users with extended reality (XR) devices will switch between different scenarios, such as editing documents while working at a desk and then transition music on their fingertips when getting up for entertainment. This requires future input devices to support interactions on any available surfaces for desktop-like experience, on-the-go scenarios, and situations in between, as well as intuitive and seamless switching between different surfaces.

To meet this requirement, we propose FlowRing, a ring-form-factor input device that supports interaction on multiple surfaces and switching between them. FlowRing recognizes user input on common surfaces such as desktops, pants, palms, and fingertips. On larger surfaces such as tables and pants, FlowRing enables precise 2D pointing to provide a full mouse-like experience. On the palm, FlowRing supports touchscreen-like swipes and taps. At the fingertips, FlowRing recognizes subtle thumb-to-index finger microgestures.

FlowRing consists of a miniature optical flow sensor, a skin-contact microphone, and an IMU. Among them, the optical flow sensor and IMU capture the movement of fingers, while the contact microphone detects the contact between fingers and a surface. Sensors and MCUs are fixed on a 3D-printed ring. The data received by the sensor is transmitted to the computer via BLE. We use real-time machine learning models to identify users' intended interactions, detect finger contact, recognize different surfaces, and classify microgestures.

In this demo, we present FlowRing's ability to support inputs on different surfaces and seamless switching between surfaces through two applications. In the example of a music player, FlowRing infers the user's posture based on the surface users interact with, and adapts UI to users' postures. The input method also automatically switches between on-surface 2D pointing and in-air microgestures to support efficient input in both in-situ and on-the-go scenarios. In the whiteboarding application, FlowRing maps inputs on different surfaces to operations on different UI widgets based on affordance, achieving automatic switching of UI widgets control based on the surface.

2 IMPLEMENTATION

The hardware prototype of FlowRing involves the integration of low-power sensors in a discreetly mounted ring-shaped device. The core sensing components include an optical flow sensor (Pixart PAT9130[1]), a contact microphone (Knowles VS200D[2]), and a 6-DOF IMU (STLSM6DS3TR-C[3]). Data from the optical flow sensor and the IMU are acquired at a rate of approximately 130 Hz and the sample rate of audio data is set at 4kHz. These data are transmitted wirelessly via Bluetooth LE to a laptop for further processing. The ring's components are mounted on a custom, 3D-printed chassis, powered by a 120 mAh lithium-ion battery, and designed to accommodate users with varying ring sizes. The prototype's design prioritizes practicality, low power consumption, and seamless user interaction.

The software running on the laptop processes the data received from FlowRing's sensors in real time. This involves two separate threads handling data from the optical flow sensor and IMU on one board, and the contact microphone on the other. Features derived from the sensor data are processed through three machine learning models: a gating model to reject non-gesture events, a microgesture classification model, and a surface recognition model. These models run concurrently to minimize latency. In a user study with 11 participants, FlowRing achieved a microgesture recognition accuracy of 93.6% across multiple sessions and 85.2% accuracy with participants not previously seen. This accuracy increased to 90.2% when provided with just four gesture examples from a new user. The average accuracy of the gating model and the surface recognition model is above 90%. The user interface, developed using PyQt5, facilitates interaction and visualization of the processed data.

3 DEMO APPLICATIONS

We demonstrate FlowRing's capability to extend interaction space across a variety of surfaces and support context-aware interaction through a music player and a whiteboarding application.

3.1 Music Player

FlowRing detects users' postures by analyzing the surfaces where their fingers are in contact and dynamically adjusts information density on the user interface to suit their current posture. When users interact on a tabletop surface, the desktop version with high-density UI is displayed for expressive experience and precise control. When users move to a couch, FlowRing recognizes that the surface has been changed to the thigh. Given that the thigh is not as smooth and wide as a desktop surface, the user interface adapts to a medium-density design to facilitate easier control and navigation. As users begin to walk, the UI transitions to a low-density miniplayer, allowing for easy navigation with swipe gestures and control of music playback with the tap gesture.

3.2 Whiteboarding Application

FlowRing facilitates seamless interaction within applications and digital environments by leveraging surface detection. It allows for multiple controls to be mapped to various surfaces based on their unique affordances. In this application, FlowRing maps the canvas to the desktop surfaces to offer a large drawing area and precise control. It allows users to draw on the canvas with a pencil tool by moving their hands like a mouse on a desk. Due to its similar size

[1] https://www.pixart.com/
[2] https://www.knowles.com/V2S
[3] https://www.st.com/en/mems-and-sensors/lsm6ds3tr-c.html

and intuitive finger drags, FlowRing maps the 2D color picker to the palm for quick color selection. Furthermore, discrete swiping microgestures detected by FlowRing provide a swift and efficient way to switch between tools, making the overall experience more fluid and intuitive.

4 CONCLUSION AND FUTURE WORK

FlowRing is a ring-form-factor input device that enables users to interact seamlessly across multiple surfaces. The demonstrated applications, including the music player and whiteboarding scenarios, showcase FlowRing's capability to adapt the user interface based on interaction context by detecting surfaces and microgestures. Moving forward, our goal is to develop highly efficient and ergonomic input methods for XR environments and to investigate potential applications in 3D interactions.

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