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All-in-One Thimble Actuator for Vibration, Pressure, and Hot Thermal Feedback

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***Abstract*—This demo presents a novel multimodal fingertip actuator that provides simultaneous vibration, pressure, and hot thermal feedback for enhanced haptic experiences in virtual reality (VR). The actuator integrates a dual-layer silicone structure for tactile feedback with hot thermal fabric elements, ensuring lightweight, flexible, and ergonomic usability. Pneumatic actuation delivers precise pressure and vibration responses, while a PID-controlled heating mechanism enables realistic thermal sensations. A VR environment was designed to demonstrate the actuator's capabilities, featuring a bowl of liquid and a stove with fire. Depending on the interaction, the scenario simulates tactile perception of vibration, pressure, and temperature simultaneously or individually.**

***Index Terms*—Multi-mode haptic feedback, pneumatic actuation, silicon actuator, hot thermal fabric.**

I. Introduction

This demo demonstrates a dual-layer silicone actuator capable of generating vibration, impact, and pressure, while also integrating thermal feedback [1], [2]. To achieve this, we incorporate two layers of Eeontex thermal fabric (Adafruit) along with Velcro to attach to the fingertip, allowing the actuator to simultaneously provide thermal, pressure, and vibration feedback, as shown in Figure 1.

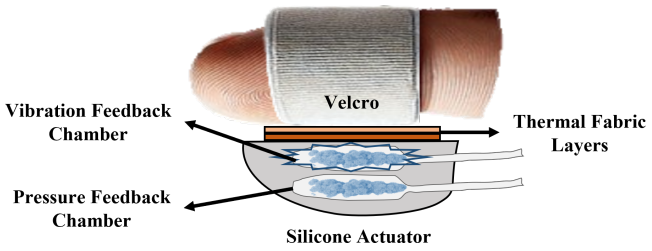

Fig. 1. Schematic diagram of the fingertip actuator.

II. Demonstration

To demonstrate the effectiveness of the proposed actuator, a virtual scenario featuring a bowl of liquid placed on a stove with fire was developed using Unity Game Engine (version 2021.3.11f1). This setup enabled users to simultaneously experience contact pressure, vibration, and thermal feedback, highlighting the actuator's multi-functional capabilities. In the virtual environment, user hand movements were tracked using a Leap Motion sensor for seamless interaction.

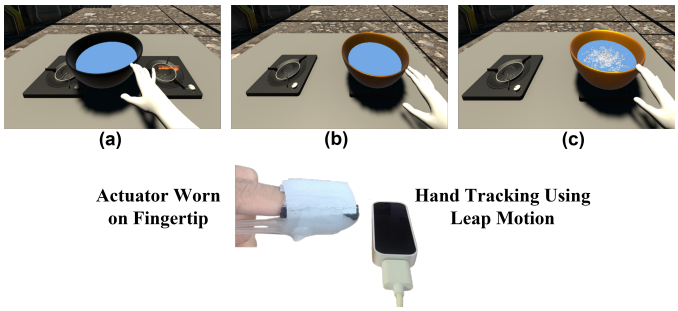

Fig. 2. Finger tracking and application used in the study. Three different interaction scenarios are implemented: (a) Contact pressure feedback only, (b) Simultaneous pressure and thermal feedback, (c) Simultaneous pressure, thermal, and vibration feedback.

Figure 2 illustrates the rendering hardware and virtual scenarios. In the VR scenario, users initially touch a bowl filled with liquid at a normal temperature, experiencing only contact pressure feedback. When the bowl is placed on a stove and the heat is turned on, the bowl changes color and begins to heat up. At this stage, users experience contact pressure and thermal feedback simultaneously. As the liquid begins to boil, users perceive simultaneous pressure, thermal, and vibration feedback. The time it takes for the liquid to begin boiling varies depending on the type of liquid.

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