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# A High-Resolution Wearable Tactile Display Using LRA Arrays*

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## I. Introduction

Commercial vibrotactile transducers are widely used to provide wearable tactile feedback in virtual reality (VR) environments. While most existing systems employ a single actuator per finger, human fingers naturally have high spatial resolution, which is essential for perceiving the edges and shapes of grasped objects. To fully leverage this capacity, a high-resolution tactile feedback mechanism is therefore considered essential.

Many wearable devices capable of high-resolution tactile feedback have been proposed [1]-[4]. However, most of these devices require the development of custom actuators.

We propose a method for achieving wearable high-resolution tactile feedback on the fingertip using commercially available small linear resonant actuators (LRAs). LRAs are among the most widely used vibration actuators today, with the smallest models measuring approximately 6 mm in diameter. By densely arranging these LRAs not only on the finger pad but also along the sides of the finger, we can provide vibrotactile feedback at nearly 30 discrete points on a single fingertip. We hypothesize that by effectively "expanding" the small contact area of the finger pad (typically less than 10 mm square) to a wider area (approximately 30 mm square including the sides of the finger), it becomes possible to convey richer tactile information, such as the perception of edge shape (Figure 1. ).

This study aims to propose a matrix-shaped tactile display for the fingertip using LRAs, based on the concept described above, and to evaluate its ability to convey edge shapes.

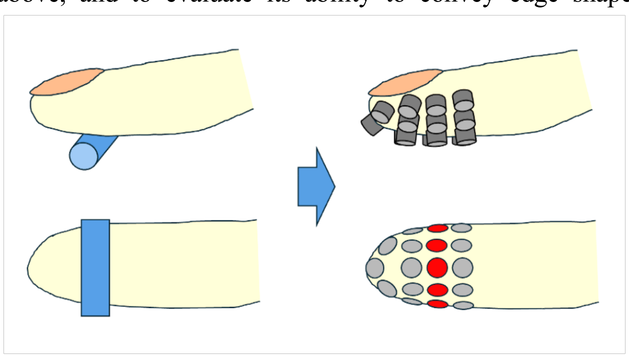

Figure 1. **Concept:** High-resolution tactile feedback using a commercial LRAs and expanding the presentation area.

## II. Apparatus

A prototype of the wearable tactile display using LRA arrays is shown in Figure 2. In this device, a cushioning material is attached to a Velcro strap to prevent vibration propagation, and the LRAs are mounted on top of it. Nine LRAs arranged in a 3×3 grid are placed on the finger pad (Figure 2. (a)); six LRAs in a 2×3 grid are placed on each of the left and right sides of the finger (Figure 2. (b), (c)); and three LRAs arranged in a 1×3 row are positioned at the fingertip (Figure 2. (d)), for a total of 24 LRAs. Each LRA is spaced approximately 1 mm apart from its neighbors.

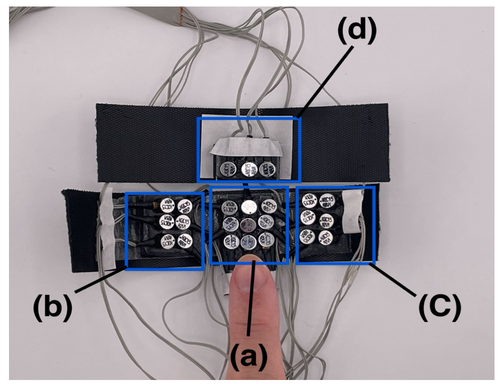


Figure 2. A prototype of the wearable tactile display using LRA arrays

## III. Experiment

This experiment aimed to evaluate the information presentation capability of the proposed vibrotactile device, with a particular focus on verifying the effectiveness of presenting vibrations not only to the finger pad but also to the sides of the finger. Three presentation area conditions were tested: (1) vibrations presented to both the finger pad and sides, (2) vibrations presented only to the finger pad, and (3) vibrations presented only to the finger sides. Four edge directions were prepared as presentation patterns—(1) horizontal, (2) 45° diagonal, (3) vertical, and (4) 135° diagonal—as shown in Figure 3. As a result, a total of 12 vibrotactile patterns were designed, based on the combination of three presentation area conditions and four edge directions ($3 \times 4 = 12$). The 12 vibration patterns are illustrated in Figure 4, where the red circles indicate the actuated vibrators. All vibrations were simple 200 Hz sine waves, and each pattern was presented for approximately 2 seconds.

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Twelve participants (10 males, 2 females; 1 left-handed, 11 right-handed), aged between 22 and 24 years, took part in the experiment. Each participant was presented with the 12 vibrotactile patterns once in a randomized order and asked to identify the perceived edge direction from the four options. This set was repeated five times, resulting in a total of 60 trials per participant.

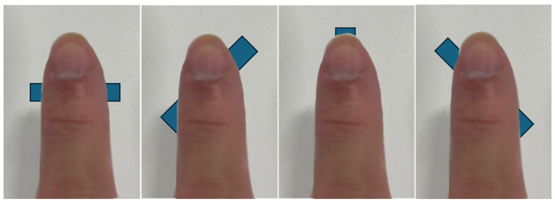

Figure 3. Four types of tactile patterns.
(From left to right: tactile patterns 1,2,3,4. )

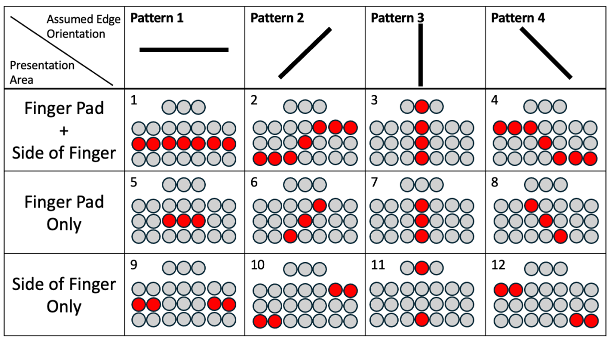


Figure 4. 12 designed vibration patterns

## IV. Results

Figure 5. shows the overall accuracy of participants' responses for each vibration pattern. Accuracy was lower for patterns corresponding to diagonal edge directions than for those corresponding to horizontal or vertical directions. The difference in accuracy between the 45° and 135° diagonal patterns may be attributed to asymmetries in contact area between the left and right sides of the finger.

Figure 6. shows the percentage of correct responses for each presentation range condition. For each participant, the percentage of correct responses was calculated for each of the three presentation range conditions, yielding a dataset of 12 participants × 3 conditions. A one-way analysis of variance (ANOVA) was conducted with the presentation range condition as a factor, followed by multiple comparisons using the Bonferroni correction.

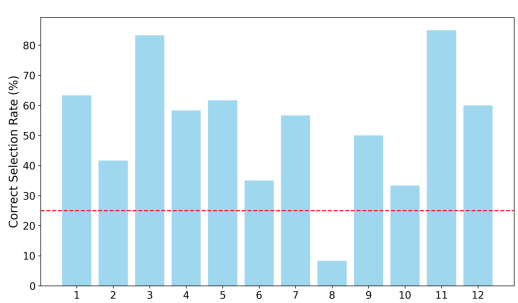


Figure 5. Percentage of correct tactile pattern responses for each vibration pattern

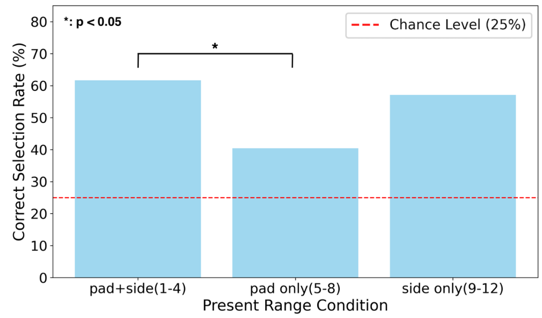


Figure 6. Percentage of correct answers by range of presentation

A significant difference was found between condition (1) finger pad + finger side and condition (2) finger pad only. The higher percentage of correct responses in condition (1) confirms the effectiveness of the proposed method, in which vibrotactile stimuli are presented not only on the finger pad but also on the sides of the finger.

## V. Conclusion and Future work

The objective of this study was to realize high-resolution tactile feedback using a vibrator matrix capable of representing the edge shape of an object in contact. In this paper, we introduced a prototype of the device and evaluated its tactile feedback capability. The results demonstrated the effectiveness of the proposed method, which presents vibrations not only to the finger pad but also to the sides of the finger.

Currently, we are developing the device embedded in a gel-type structure, as shown in Figure 6. This gel structure is designed to improve the contact area between the LRAs and the finger, enhance wearability, and increase the recognition rate of edge directions by further reducing vibration propagation. In our next step, we plan to explore vibration presentation methods that enable more precise recognition of edge shapes, such as varying the frequencies of adjacent vibrators, as well as expanding the device to each finger or even the entire hand.

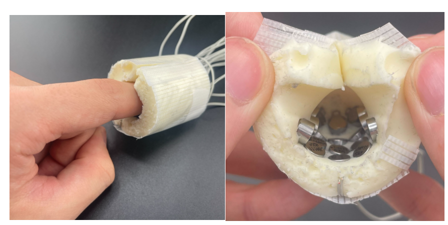

Figure 7. Devices under improvement

## References


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