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Low-Cost Electroadhesive User Interface for Localized Multi-Finger Haptic Interaction

Emir Bahadır Ünsal*, Can Berkay Akkaya†, Evren Samur†, Çağatay Başdoğan*
*Department of Mechanical Engineering, Koç University, Istanbul, Turkey
†Department of Mechanical Engineering, Boğaziçi University, Istanbul, Turkey

***Abstract*—Electroadhesion enables the modulation of friction between a human finger and a voltage-induced touch surface [1]. Most earlier implementations of this technology were limited to single-finger interactions, as the use of a single-layer conductive coating prevented localized and multi-finger control. The ability to provide localized, multi-finger tactile feedback holds significant potential for enhancing non-visual interaction experiences, particularly for visually impaired and blind users.**

This work presents a low-cost electroadhesive user interface featuring a grid-patterned conductive layer fabricated directly onto a standard FR4 PCB substrate. Each square cell of the 4×4 grid, sized at 6 mm, can be actuated independently. Our design enables multi-finger localized haptic feedback by directly addressing the desired cells.

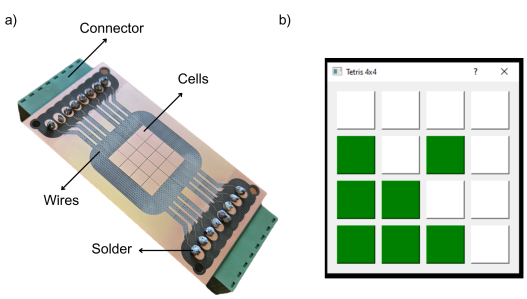

Fig. 1. (a) Low-cost electroadhesive touch surface that enables visually impaired and blind users to experience localized, multi-finger tactile feedback. The surface consists of a 4×4 grid-patterned conductive layer fabricated directly on a standard FR4 PCB substrate, coated with a SiO_2 insulator layer. Each cell of the grid can be independently actuated by a voltage signal via solid-state relays. The labeled image shows key components including the connector, wires, solder joints, and the individually addressable cells. (b) Screenshot from a custom Tetris-style game interface used to demonstrate localized tactile feedback. As the user plays the game, the tactile display activates specific cells corresponding to the falling blocks, allowing gameplay using touch alone.

The PCB was designed using Altium Designer and fabricated with an LPKF ProtoLaser U4 system. Pre- and post-fabrication cleaning involved sequential acetone and IPA treatments, followed by nitrogen drying. A 1 μm thick SiO_2 dielectric layer was deposited via ICP-CVD (SI 500D, Sentech Inc.). Soldering was applied to the uncoated areas protected by masking tape during deposition. Each cell is driven by two programmable eight-channel solid-state relays (Yocto-MaxiCoupler, Yoctopuce Inc.), each capable of switching within 1 ms and tolerating up to 120 V AC.

To deliver voltage to the grid cells, a signal generator produces ± 2 V, 125 Hz square waves, which are amplified fifty-fold and routed to individual cells via relays. A custom software interface enables precise per-cell control, supporting interactive tactile experiences such as haptic-enhanced games.

This demonstration showcases the ability to play a simplified version of the well-known game Tetris relying solely on tactile feedback. During the game, a square falls from the top of the grid. The user can move the square left or right via the arrow keys on the keyboard as they fall. The aim is to complete a line by filling every square across the bottom row without gaps, which disappears when it is complete. The user is notified of point gains through audio feedback. The game ends if the blocks pile up to the top of the screen.

***Index Terms*—Surface haptics, electrovibration, electroadhesion, printed circuit board, multi-finger interaction, localized tactile feedback**

References

[1] C. Basdogan, F. Giraud, V. Levesque, and S. Choi, "A review of surface haptics: Enabling tactile effects on touch surfaces," *IEEE Transactions on Haptics*, vol. 13, no. 3, pp. 450–470, 2020.