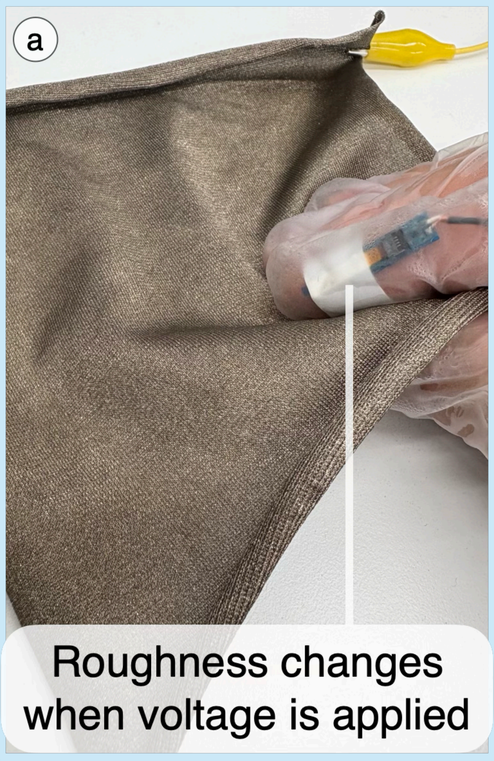
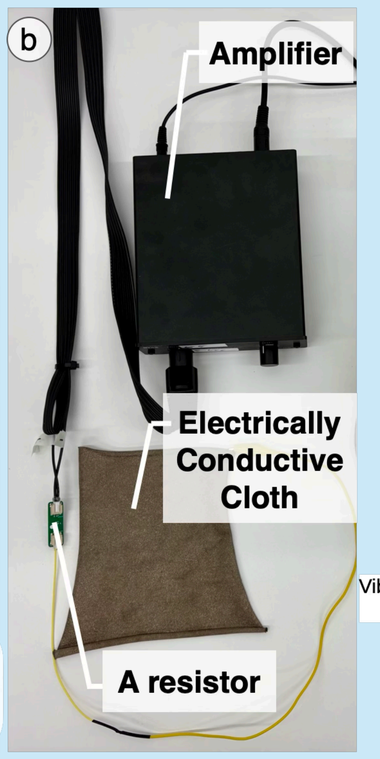
Pinching Tactile Display:

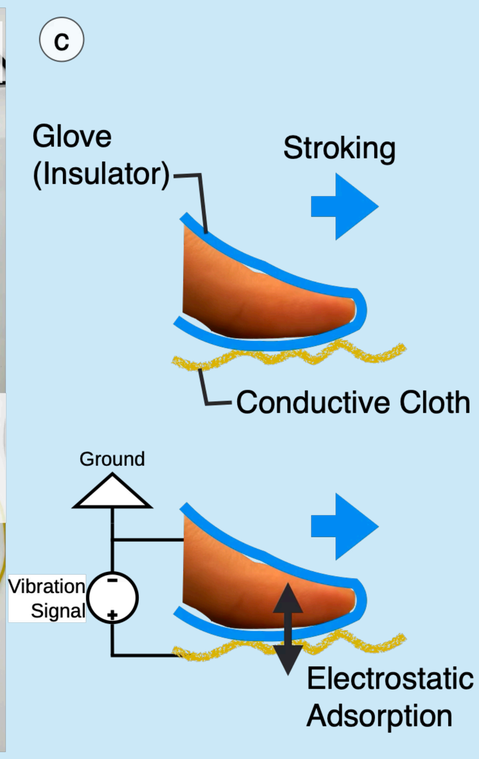
End-to-end Transmission of Fabric Roughness via Electrostatic Adsorption

Takekazu Kitagishi[1,2], Qing Zhang[1], Jun Rekimoto[1,3]

[1]The University of Tokyo, [2]ZOZO Research, [3]Sony CSL Kyoto







Key Results:

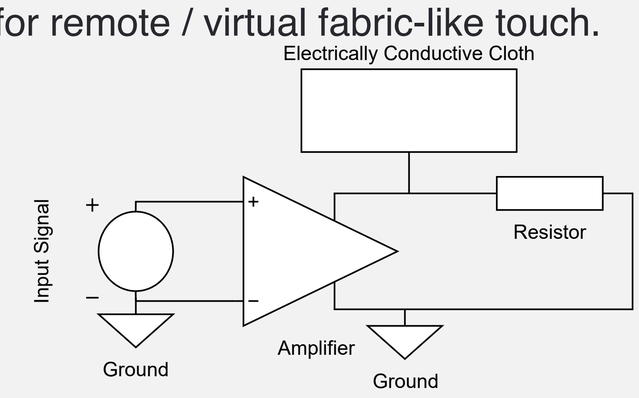
1. **End-to-end input:** Accepts **measured fabric vibration** as input toward replaying real tactile data on fabric.
2. **Perceptual control:Voltage** drives **bumpiness** (and **roughness); frequency** drives **stickiness**; roughness span **2.1–3.0** on 5 scale Likert.
3. **Physical validation:** Input–finger vibration correlation **significantly higher** for matching vs mismatched signals **(p = 0.008),** supporting reliable transmission.

Background

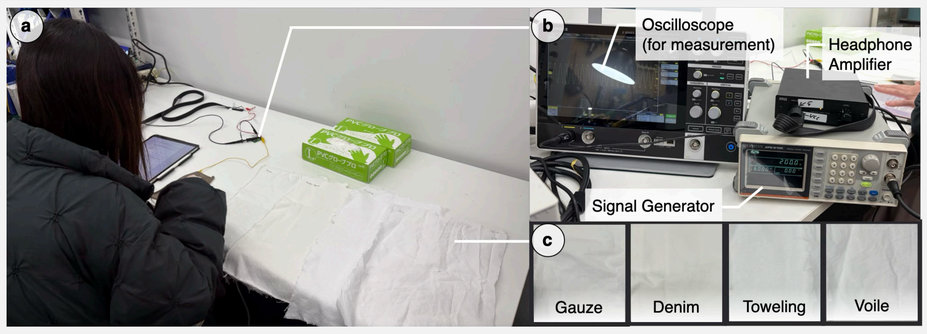
- Fabric tactile sensation is hard to transmit remotely (softness, delicacy, fine surface texture).
- Prior end-to-end systems emphasize rigid surfaces; fabric-specific solutions are limited [1].
- Prior electrostatic fabric displays cannot take **recorded vibration** as input [2].

System Configuration

- **Pinching Tactile Display:** conductive fabric + **bipolar** amplified signal → electrostatic adsorption modulates sensation at the finger.
- **Use case:** replay **fabric-captured** vibrations for remote / virtual fabric-like touch.



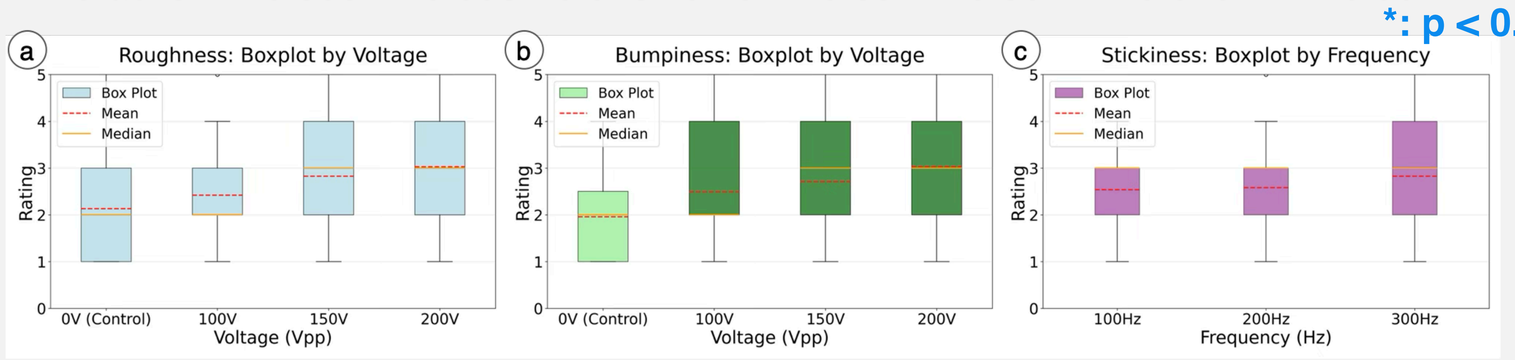
Evaluation 1 - perceptual



- **N = 23**, **Voltage × Frequency** full within-subjects factorial (sinusoidal stimuli; 100, 200, 300 Vpp and 100, 150, 200 Hz).
- Four **fabric** dimensions (roughness, thickness, stiffness, warmth); Four **electrostatic** dimensions (bumpy, sticky, pleasant, friction).
- **Aligned Rank Transform (ART)** + two-way ANOVA; post-hoc **Hommel**

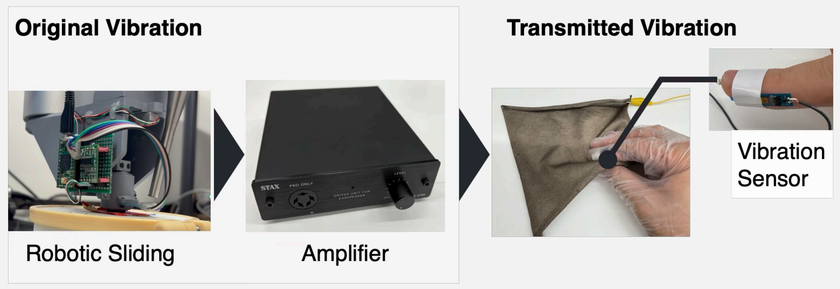
Effect	Rough	Thick	Stiff	Warm	Sticky	Bumpy	Pleasant	Friction
Voltage	**0.037***	0.314	0.528	0.192	0.806	**0.024***	0.640	0.413
Frequency	0.885	0.577	0.430	0.138	**0.025***	0.867	0.640	0.439
Interaction	0.355	0.658	0.528	0.291	0.892	0.867	0.640	0.562

*: $p < 0.05$

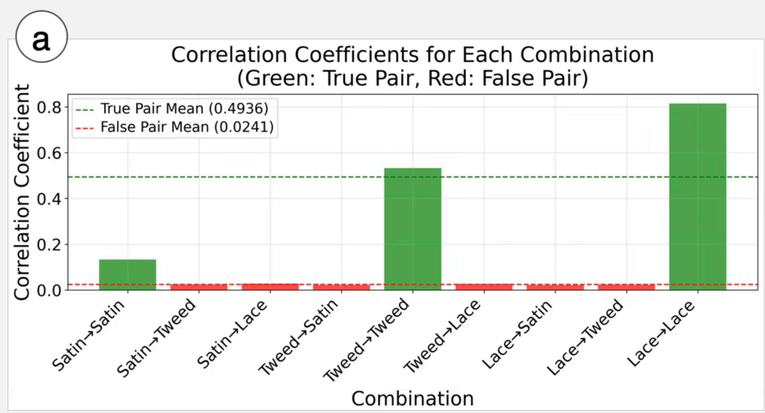


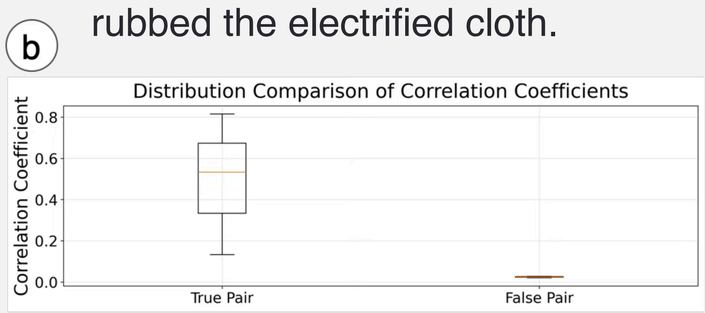
- **Roughness range (means): 2.13** to **3.03** on the 5 liker scale — suggestively comparable to fine-textile differences (gauze / voile region).
- **Voltage** mainly modulates **bumpiness** (and perceived **roughness**); **frequency** modulates **stickiness**; effects are largely **additive** on roughness-related perception.

Evaluation 2 — input–output vibration



- Vibration signals recorded from three fabrics (**Satin**, **Tweed**, **Lace**) with a **robotic arm**
- **Picoleaf** (biodegradable piezoelectric) sensor on the **fingertip**; participants rubbed the electrified cloth.





- Analysis: correlation between **input** signal and **finger** vibration; **matching** (same fabric) vs **mismatched** pairs; independent samples.

Limitations & Future Work

- **Gloves; high voltage** (up to **200 Vpp** in Evaluation 1); modulation mainly on **roughness / bumpiness / stickiness**.
- Future: **glove-free** operation, broader perceptual modulation, applications on remote try-on, VR, e-commerce.

Reference

[1] Minamizawa, K., Kakehi, Y., Nakatani, M., Mihara, S., & Tachi, S. (2012). TECHTILE toolkit: A prototyping tool for design and education of haptic media. *VRIC '12*, 1–4. DOI: 10.1145/2331714.2331745 [2] Kitagishi, T., Hiraki, H., Nakamura, H., Ishiguro, Y., & Rekimoto, J. (2024). Pinching Tactile Display: A cloth that changes tactile sensation by electrostatic adsorption. *AVI '24*, 1–9. DOI: 10.1145/3656650.3656690