Touch-Linked Sleeve: A Haptic Interface for Augmented Tactile Perception in Robotic Teleoperation

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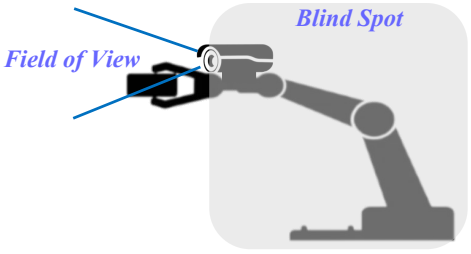
Motivation & Challenge

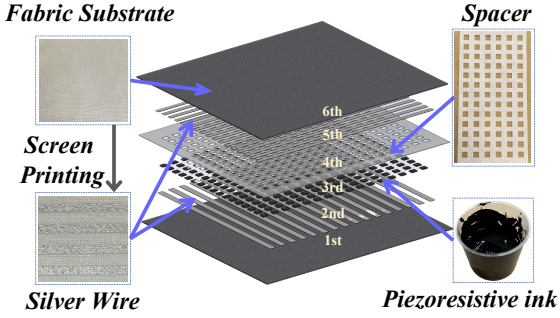


Robotic arms lack large-area tactile sensing.

This results in blind spots and limited situational awareness during teleoperation.

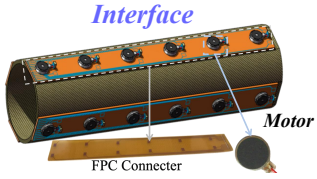
Hardware Design

(1) Fabric Robot Tactile Skin



Our tactile skin is highly flexible, and offers high resolution, and large-area coverage.

(2) Wearable Vibrotactile Interface

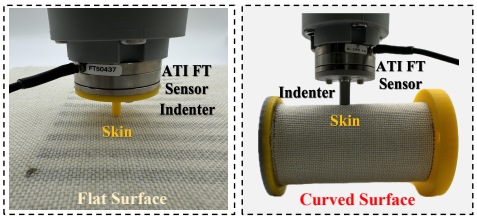


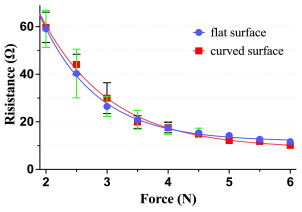
We created a vibrotactile haptic acutator array that maps robot contact to operator's arm.

Methodology

(1) Force Sensing

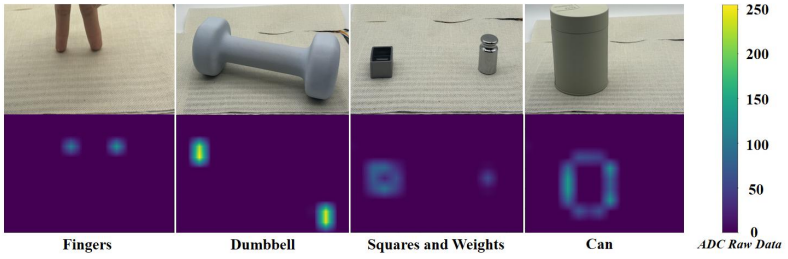
Consistent sensitivity on both flat and curved surfaces.



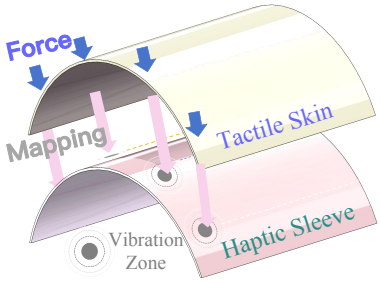


(2) Contact Localization

High density taxels offer contact localization capability.

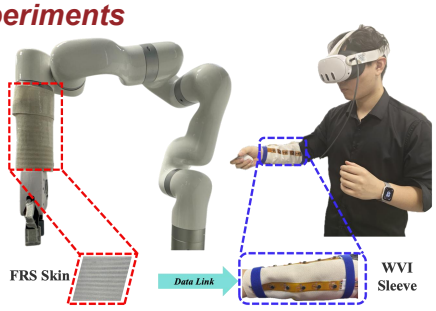


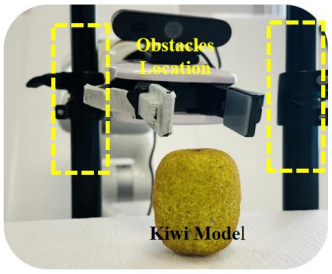
(3) Haptic Mapping

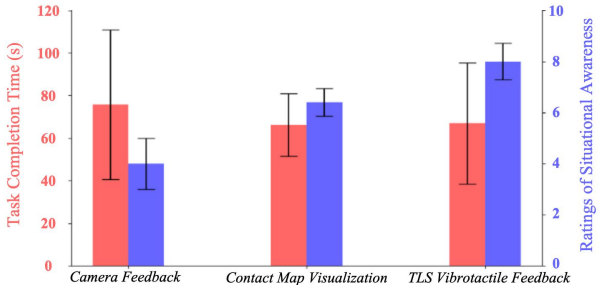


A mapping rule is designed to map sensor readings to vibration intensity of wearable vibrotactile interface.

Experiments







- Users controlled the robot arm via VR teleoperation. The goal is to reach through obstacles and grasp a kiwi model.
- Three conditions were compared:
  - Baseline 1: Camera Feedback Only (longest completion time, many collisions).
  - Baseline 2: Contact Map Visualization (improved completion time, fewer collisions).
  - Ours: TLS Vibrotactile Feedback (best situational awareness, reduced collisions, efficient task performance).

Results: TLS users reported highest situational awareness ratings and achieved efficient, safe manipulation.

Discussions and Acknowledgement

Limitation: Limited region (only front arm).
Future work: Design gloves for anthropomorphic hands.
Acknowledgement: Approval of all ethical and experimental procedures and protocols was granted by ShanghaiTech University's ethics review board (No. Q2024-018), and performed in line with the declaration of Helsinki.

Conclusions

Tactile perception is essential for telerobots in cluttered tasks. We propose the Touch-Linked Sleeve: fabric-based tactile skin for large-area contact perception. The detected contact is mapped to a vibrotactile sleeve. Teleoperation experiments show improved situational awareness, fewer collisions, and faster task performance, showcasing efficacy of our design.