TouchDrive: Electronics-Free Tactile Sensing Interface for Assistive Grasping

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Introduction

Haptic feedback enhances contact-rich manipulation in surgery, teleoperation, and assistive grasping. Yet most interfaces still rely on **electronics and multi-stage pipelines** [1, 2, 3], that separate sensing, processing, and feedback, increasing complexity and forcing operators to rely on indirect modalities (electrotactile, vibrotactile, or visual cues). As a result, operators often depend on visual or mediated feedback [2], creating a separation between physical interaction and perception, particularly when handling compliant or fragile objects where over-grasping and delayed correction remain common [4]. To address these limitations, we present **TouchDrive**, an electronics-free tactile sensing interface that directly transforms contact forces into pneumatic haptic feedback through a passive valve-mediated mechanism. By embedding sensing, signal generation, and feedback within a physically coupled pneumatic loop, **TouchDrive** enables intuitive and responsive assistive grasping without electronics, controllers, or computational processing.

Key Contributions

- Electronics-free tactile sensing interface
- Integrated sensing and feedback loop
- Gentle manipulation of fragile objects
- Low-cost, portable and scalable implementation

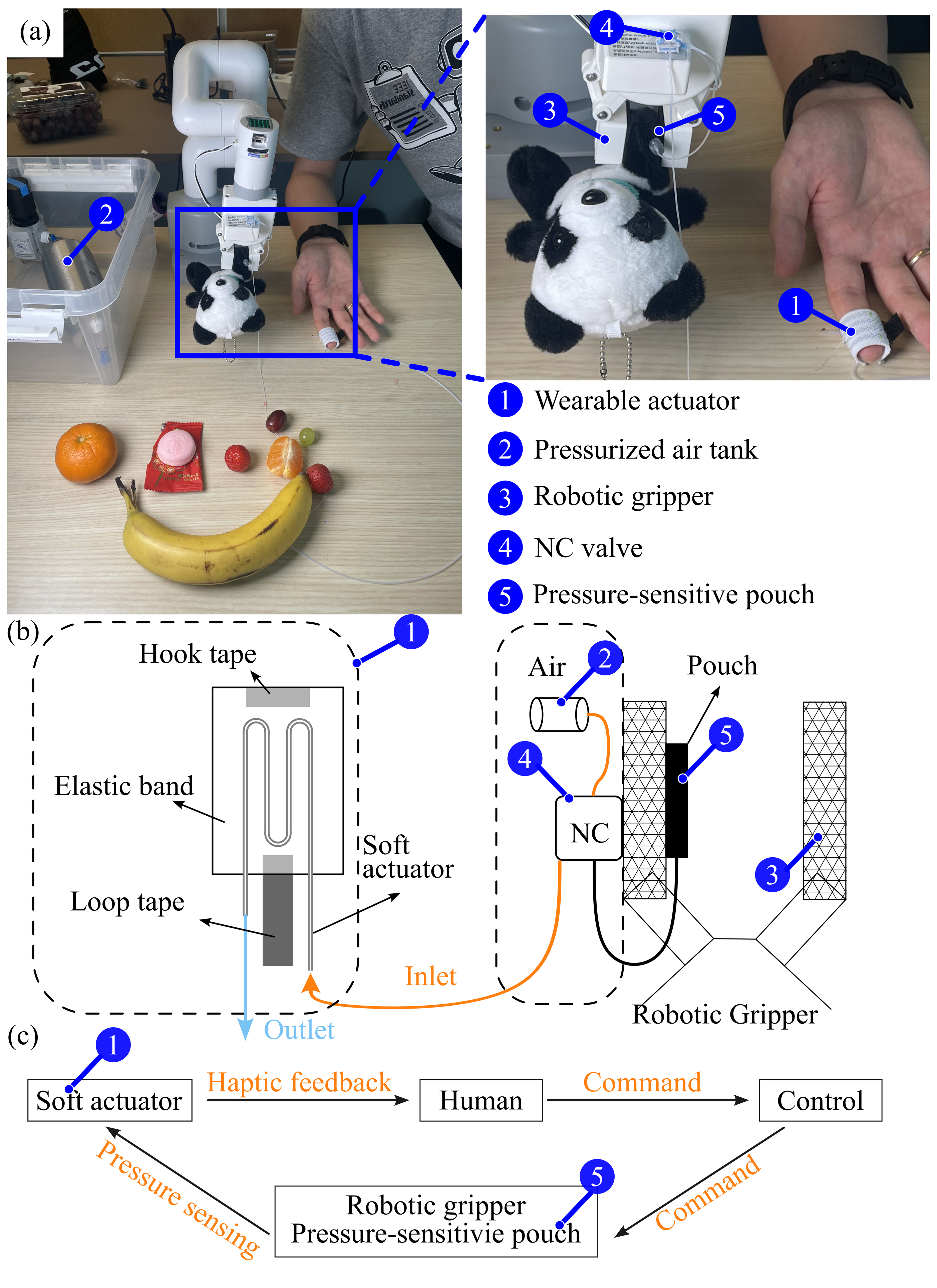

Figure 1. System overview of the assistive grasping system. (a) Experimental setup showing the robotic gripper, pressure-sensitive pouch, NC valve, air supply, and wearable pneumatic actuator. (b) Pneumatic interface schematic illustrating airflow paths, valve operation, and mechanical integration. (c) Haptic interaction diagram, where contact-induced pressure changes are conveyed to the user as pneumatic feedback for grasp adjustment.

Experiments and Results

- **System Characterization** Results showed clear stiffness-dependent behaviour. Softer materials exhibited gradual force and airflow changes with larger deformation, whereas harder materials generated steeper responses and earlier airflow activation. The observed hysteresis between loading and unloading confirmed the elastomeric characteristics of the passive sensing mechanism, contributing to stable valve switching and repeatable tactile feedback generation.

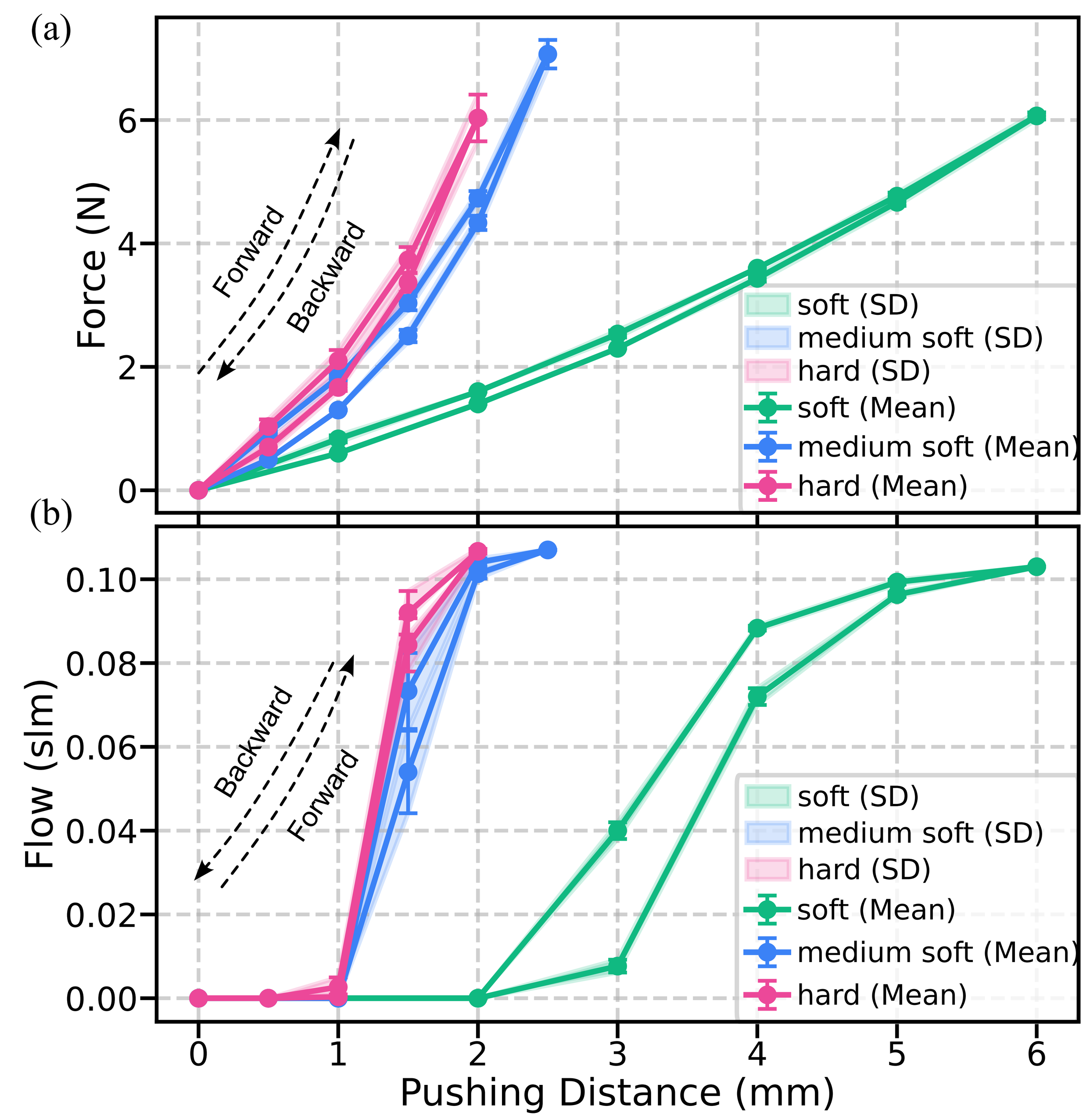

Figure 2. Experimental characterization of three silicone cubic with different stiffness (soft, medium soft, hard). (a) Force versus displacement during forwarding and backward motion, showing steeper responses for harder samples and larger deformation for softer ones. (b) Flow versus displacement, with softer samples requiring greater displacement to initiate flow. Shaded regions and error bars denote standard deviation across trials.

- **Assistive Grasping with myCobot 100% grasp success:** Users controlled grasp force through pneumatic feedback alone, enabling delicate object handling without electronics or visual assistance.

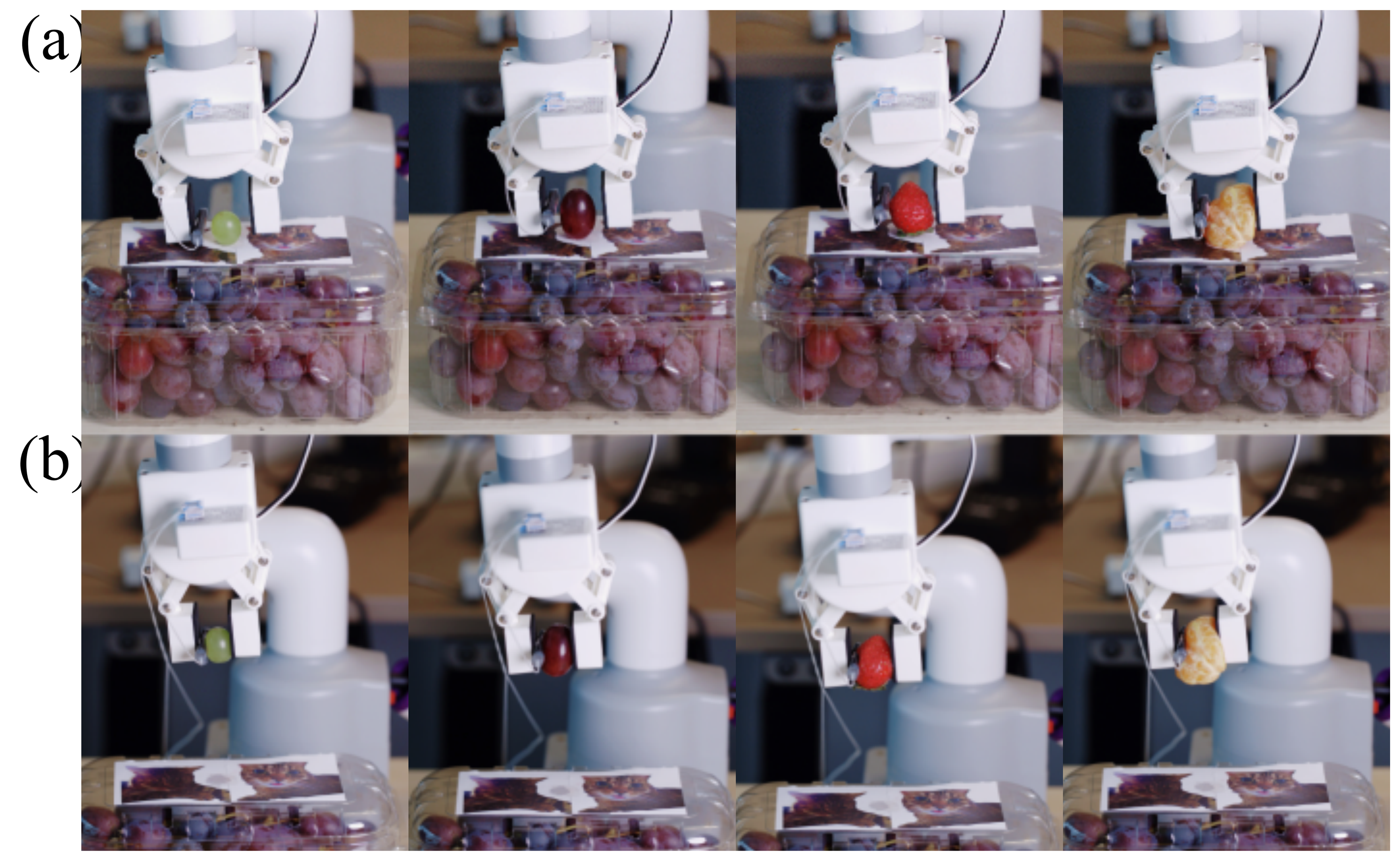

Figure 3. Grasping fruits with myCobot using the proposed system. (a) Pre-grasp configuration over mixed fruits. (b) Stable grasping and lifting via pneumatic feedback, demonstrating adaptability across objects.

- **Validation on Industrial Cobot Cross-platform grasping:** TouchDrive reached an average grasping score of **0.94** on a Dobot Nova 5 with a Robotiq 2F85 gripper, including perfect performance on eggs, strawberries, grapes, and tomatoes. In the paper-cup task, built-in force control lifted the whole stack, while TouchDrive allowed users to grasp single cups through pneumatic feedback.

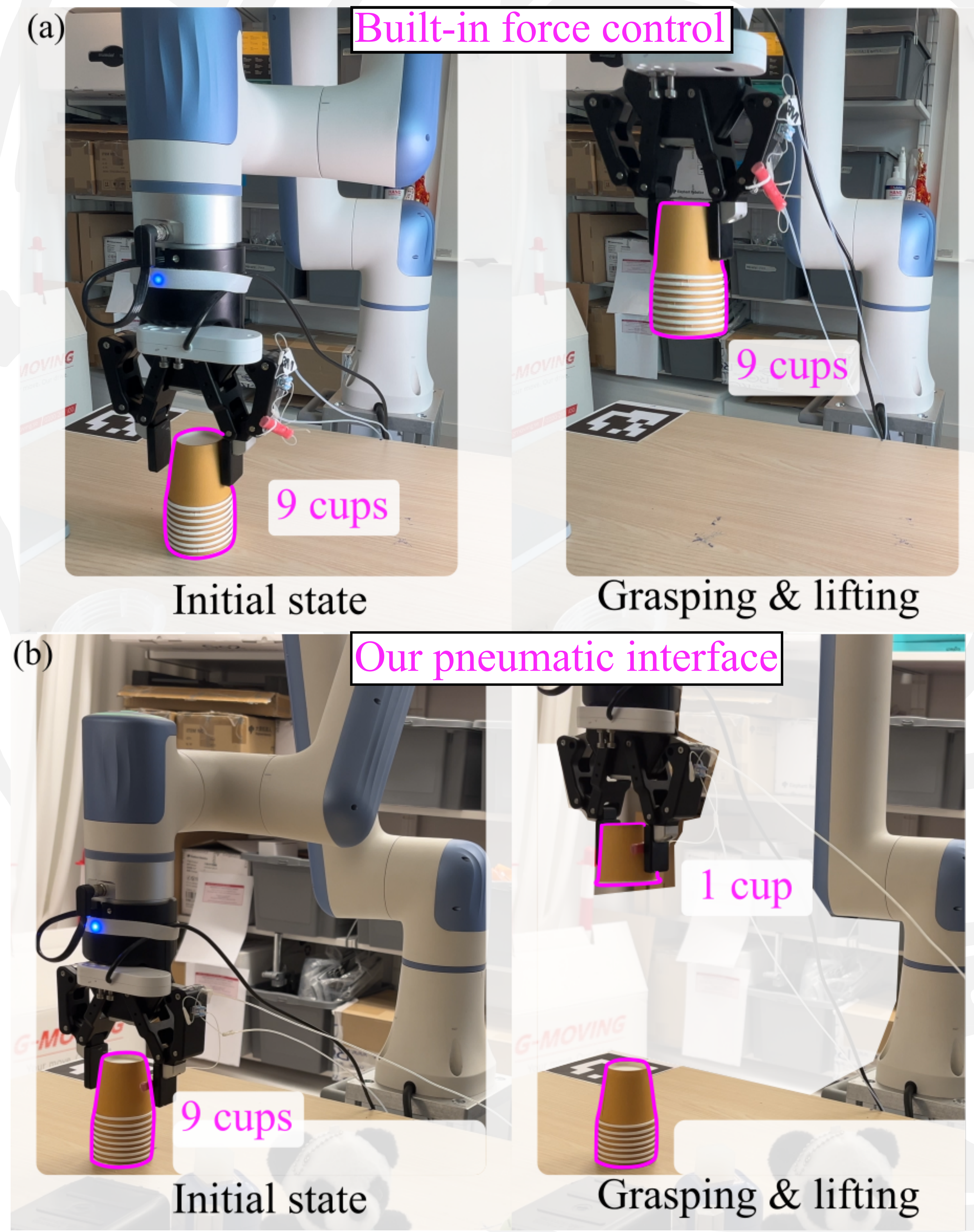

Figure 4. Nine-cup stack. (a) Built-in 20 N force control lifts *all* cups. (b) **TouchDrive** enables **selective single-cup grasp at sub-newton scale**.

Discussion

The results demonstrate that physically coupled pneumatic feedback can provide interpretable tactile information without electronics or computational processing. The modular and low-cost architecture makes **TouchDrive** particularly attractive for assistive robotics, soft robotic systems, and portable haptic interfaces where simplicity, robustness, and accessibility are critical.

Takeaways

- **Electronics-free** loop – sensing, signal, and feedback in one passive mechanism.
- **Sub-newton, damage-free** grasping of fragile objects via direct pneumatic cues.
- **Platform-agnostic** – portable across payloads and gripper types.

References

[1] A. M. Okamura, "Methods for haptic feedback in teleoperated robot-assisted surgery," *Industrial Robot: An International Journal*, vol. 31, no. 6, pp. 499–508, 2004.

[2] C. Pacchierotti and D. Prattichizzo, "Cutaneous/tactile haptic feedback in robotic teleoperation: Motivation, survey, and perspectives," *IEEE Transactions on Robotics*, vol. 40, pp. 978–998, 2023.

[3] D. Sieber, S. Musić, and S. Hirche, "Multi-robot manipulation controlled by a human with haptic feedback," in *2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2015, pp. 2440–2446.

[4] Z. Cheng, X. Tian, R. Sui, T. Li, and Y. Jiang, "An adaptive grasping force tracking strategy for nonlinear and time-varying object behaviors," *IEEE Transactions on Automation Science and Engineering*, vol. 22, pp. 17 063–17 076, 2025.

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