Controlling Palm-Object Interactions via Friction for Enhanced In-Hand Manipulation

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Introduction

In-hand manipulation is a critical skill for real-world robots, but most hand designs focus on developing highly-dexterous fingers.

We achieve **higher whole-hand dexterity** without changing finger complexity by adding **controlled friction forces between objects and the palm** with 1 DOF.

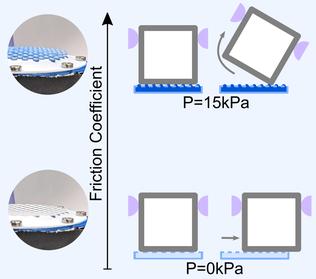
Our **active palm designs enhance in-hand manipulation** capabilities and improve grasp stability.

Two Palm Designs

Variable-friction palm

A soft high-friction membrane is stretched underneath a rigid, low-friction, porous surface.

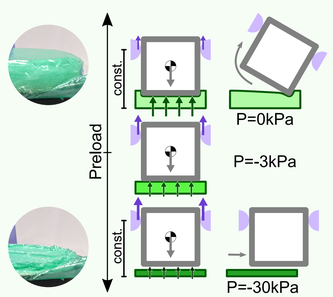
At rest, the low friction shell touches the object. Under pneumatic actuation, the **soft membrane is pushed through holes in the shell, increasing the coefficient of friction** of the palm's surface.



Variable-preload palm

A cylinder of compliant, open-cell foam is housed inside a thermoplastic elastomer pouch.

Initially, the pouch is compressed slightly by a slight negative air pressure. During a grasp, the fingers hold the object in place against the palm while the **palm is inflated or deflated to modulate the normal force between the palm and object.**



Discussion & Conclusions

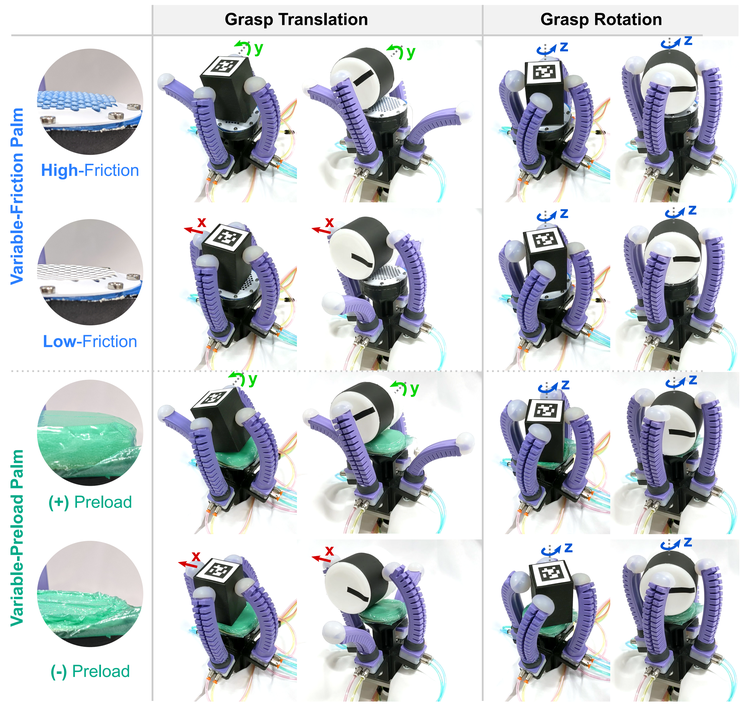
An active palm that **controls contact constraints can enhance the in-hand manipulation** capabilities of soft robotic hands with **limited finger dexterity**.

Controlling the **frictional characteristics of the palm allows for control of grasp stability**, but the upper bound is limited.

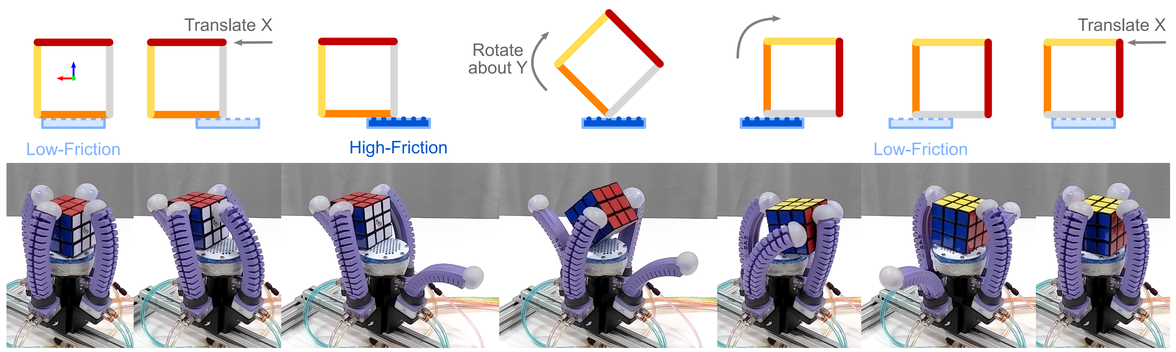
The palm's compliance, plasticity, and conformability can play a large role in the success of in-hand manipulation tasks (future work will explore these).

Results (In-Hand Manipulation)

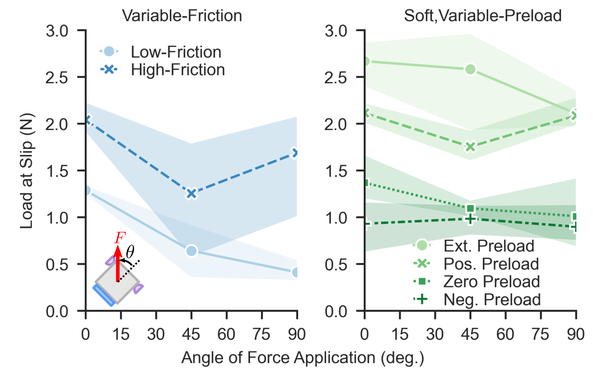
Active control of the palm's friction forces enables **access to different sets of motion primitives** by sliding and pivoting objects.



Combinations of sliding and pivoting motions enable the hand to perform **arbitrary pose shifts on objects** without increased finger dexterity.



Results (Grasping)



"Initial grasp stability" is related to friction forces applied by the palm on the object.

For the variable-friction palm, the high-friction state has 2x higher grasp stability. For the variable-preload palm, the grasp stability increases as a function of the preload, with an external preload on the object resulting in a 2.5x increase.

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