Multi-Dimensional Compliance of Soft Grippers Enables Gentle Interaction with Thin, Flexible Objects

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Introduction

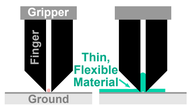
Grasping and manipulating thin, flexible objects **(fabric, tape, bags, etc.)** is an essential skill for robots to achieve in the home, in built settings, and more-remote environments.

We investigate the role of gripper compliance in **successful, safe grasping and manipulation** of thin, flexible materials.

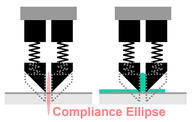
We show that for a planar gripper, all three axes of compliance each contribute to **prevent damage to the material.**

Conceptual Analysis

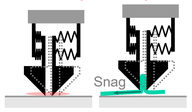
Compliance in three axes is critical for grasping **thin objects from a surface**, while also **enabling snag-resistance:**



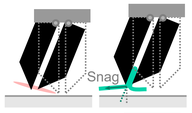
Zero compliance: large forces are applied in the presence of uncertainty



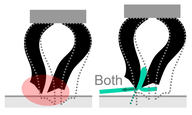
Vertical compliance: minimal forces are applied under **vertical uncertainty**



Lateral compliance: forces are applied slowly during **snags**



Rotational compliance: **tensile forces are redirected away** from the lateral direction during a snag



Compliance in 3 axes: gracefully handles **vertical uncertainty and snags**

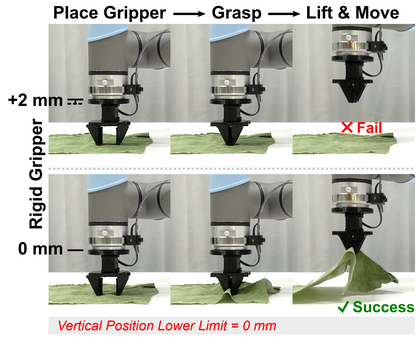
Discussion & Conclusions

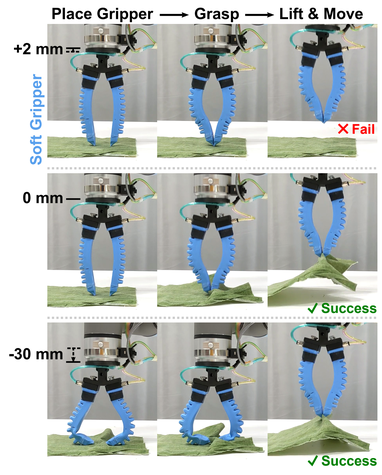
Vertical compliance in a gripper enables **gentle, force-limited actions** with a solid surface (such as a table). This can be particularly useful in situations where visual perception is difficult or unreliable.

During a snag, **rotational and lateral compliance** serve to:
1) **decrease the maximal tensile force** applied, leading to passive force-limited grasps and
2) increase the time over which these forces are applied, directly **reducing the sensing bandwidth required** to detect snags.

Future studies include variable-stiffness actuators and onboard sensing to make the best use of control and mechanical compliance.

Results (Vertical Offsets)



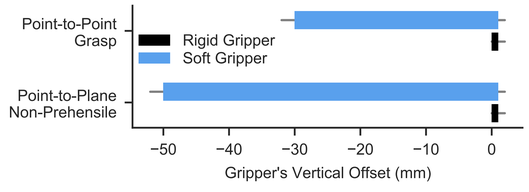


A **rigid gripper**'s low compliance **induces large normal forces** under uncertainty in vertical positioning.

This makes it **difficult to grasp** thin objects, and potentially **causes damage.**

A **soft gripper**'s high vertical compliance **ensures force-limited contact with the swatch**, even **under large uncertainty** in the vertical direction.

For both prehensile and non-prehensile grasps, our **soft gripper successfully manipulates swatches despite large vertical offsets.**



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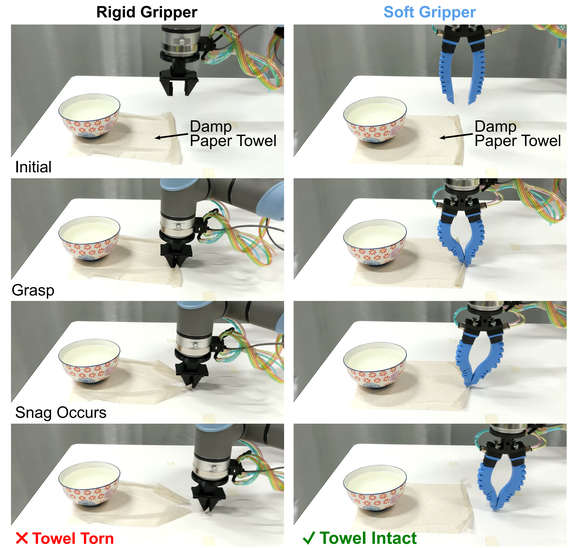
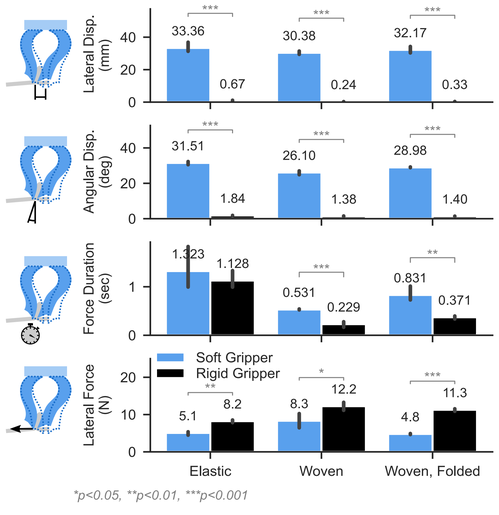
Results (Snags)



During snags, a **rigid gripper's** low compliance results in **high tensile forces applied quickly.**

Our **soft gripper**'s lateral and rotational compliance **limit the magnitude** and **extend the duration of snag forces** via mechanical deflection, **avoiding damage.**



*p<0.05, **p<0.01, ***p<0.001