A Variably Compliant Gripper Enabled by Embedded Shape Memory Alloy

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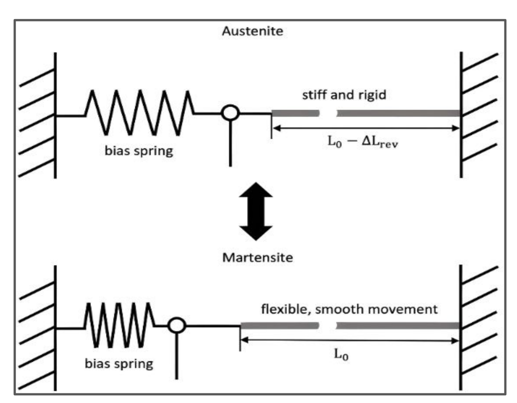
Overview

- We developed flexible fingers embedded with SMA that allows dynamic compliance adjustment that are attached to an angled robotic gripper.
- The purpose of this project is to develop a scalable robotic gripper that can dynamically strengthen soft grippers for soft material handling. We comparatively tested this gripper to three other gripper types.

Introduction

Fig. 1: SMA stiffness change



- Fig.1 shows an axial loading stiffness change of SMA as it relates to the austenite and martensite phases, we expect this to a similar case for embedding SMA into a gripper (bending) [1].
- We know that the electrical power is equal to the joule heating [2]:

$$I^2R = m\left(c\Delta T + L_f\right)$$

- We can find the resistance R knowing the resistivity [2]:

$$R = \rho(L/A)$$

- We implement a fin-ray gripper that tends to increase gripper contact with the object that was 3D printed with a flexible material called TPU [4].
- We seek to strengthen the compliant gripper by embedding a Shape Memory Alloy (SMA), specifically nitinol (Ni-Ti).

Methods

- We used an existing fin-ray finger design and added through-holes for embedding a single continuous SMA wire per fin (Fig. 2).
- Developed a gripper mount testing apparatus (Fig. 4) and data logging with redundant FSRs.
- Tested five types of grippers, we define the two SMA gripper types by their length [L] embedded into the fin: (A) L(SMA)=14.2cm, (B) L(SMA)=7.2cm, (C) spring steel embedded fin, (D) fin only, and (E) base gripper.

Fig. 2: Fin-ray finger

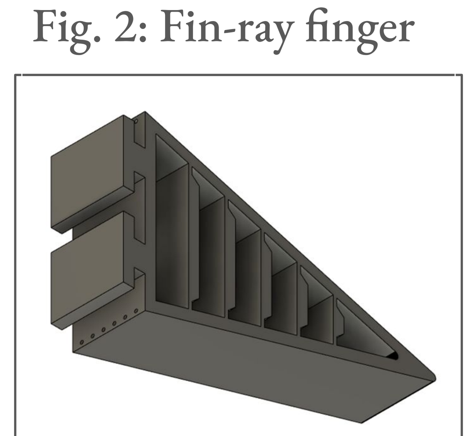


Fig. 3: Gripper sample results

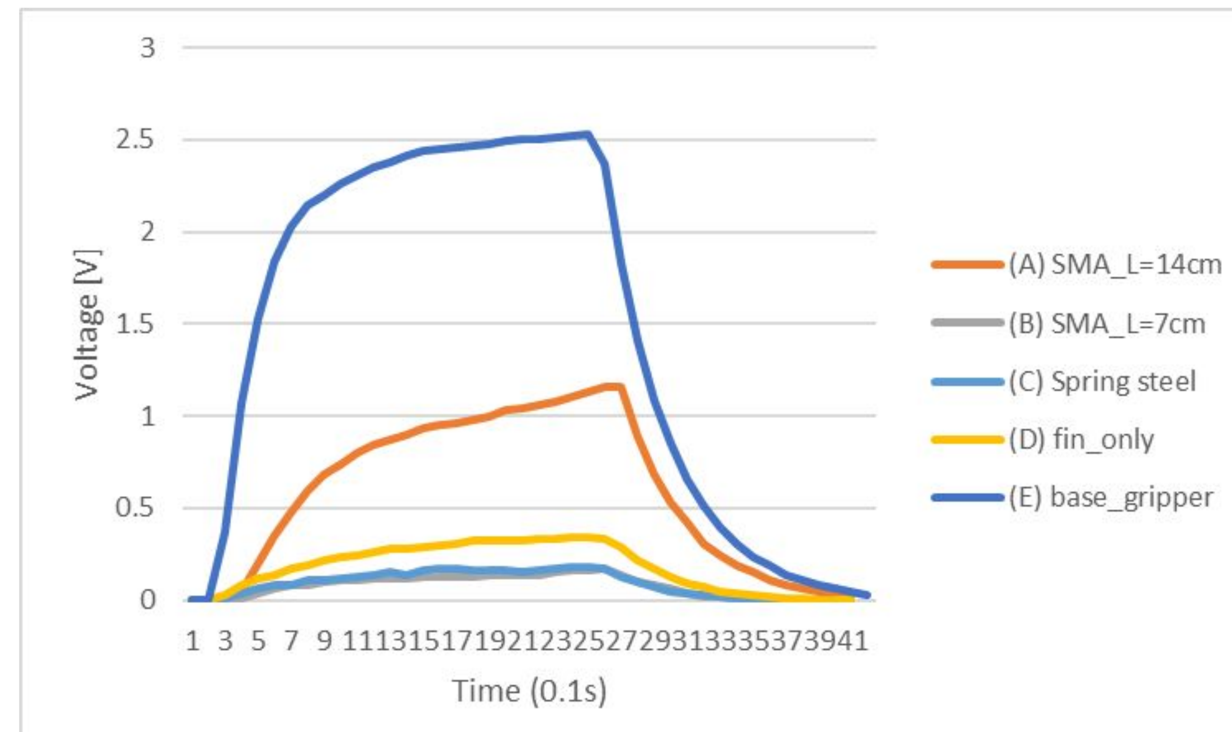
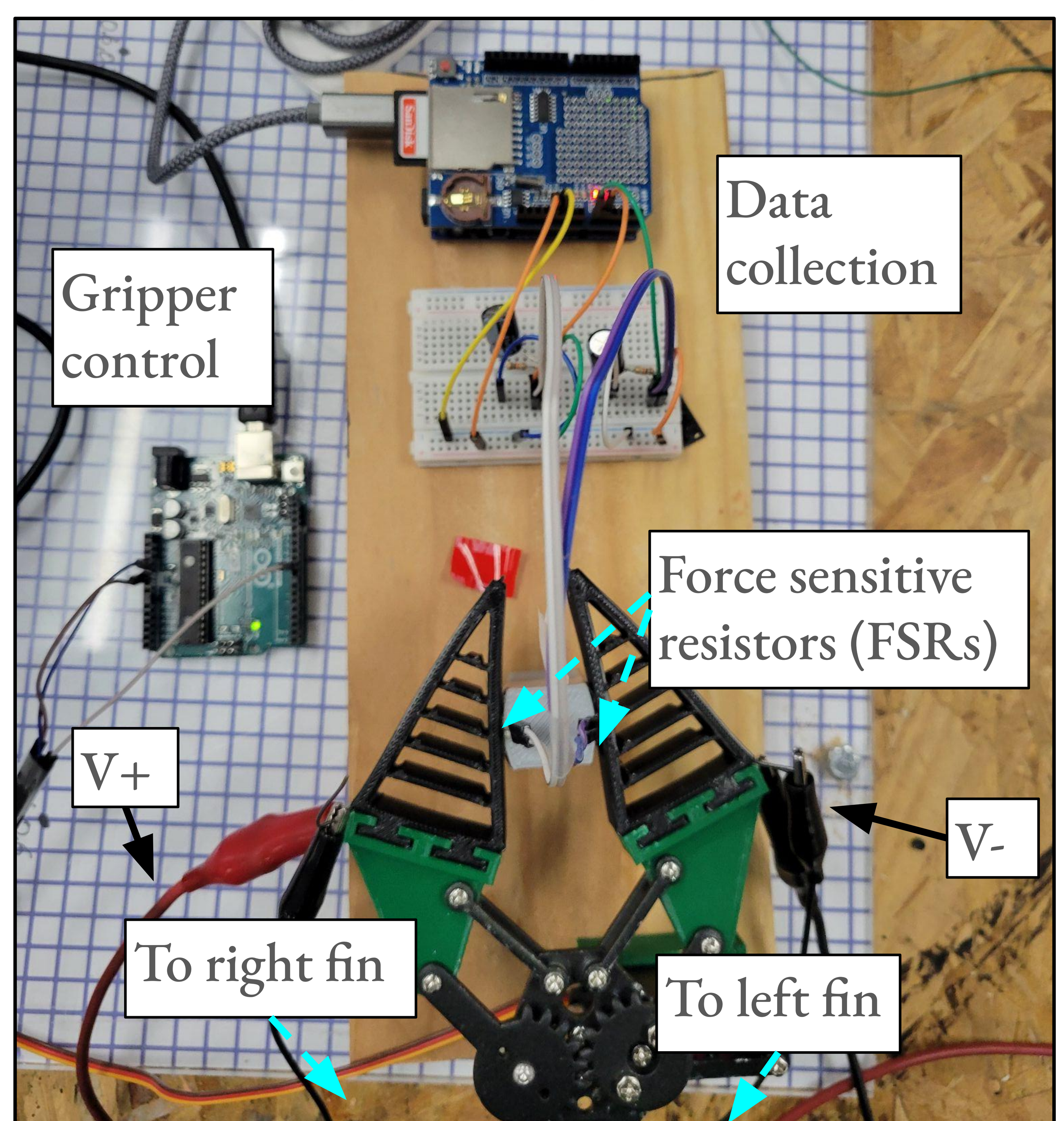


Fig. 4: Testing apparatus



Results

- We tested the grippers repetitively performing 20+ trials per gripper and found that (E) had the highest force results (Fig. 3). And following is (A) with the full embedded 14cm of SMA requiring 6W.
- The direct SMA required about 5W but did not seem to have ideal results, scoring low near the spring steel.
- This is likely an error with the data collection design as its more reliable range is above (0.25kg) per the calibration results.
- We found that the base gripper has a capability of up to 4.905 N.

Conclusion

- We found that we could strengthen a compliant gripper with SMA embedded with the highest results of the (A). The purpose of this project is to use a compliant gripper which can change the stiffness according to the input voltage that does not deform the object.
- For future work, the gripper needs a higher current supply for the servo for higher grasping torque and gripper design the gear system to reduce backlash, and to expand the gripper mouth.
- For use in lunar exploration environments, where the temperature change is more significant, the power needed for SMA would be greater depending on the temperature difference.

Citations:

[1] "Activating Nitinol with Electric Current." Accessed: Jan. 10, 2024. [Online]. Available: https://www.imagesco.com/articles/nitinol/06.html

[2] "Nitinol Technical Basic FAQ - Kellogg's Research Labs." Accessed: Jan. 10, 2024. [Online]. Available: https://www.kelloggsresearchlabs.com/nitinol-faq/

[3] U. Scholar, "Design and Testing of Fin Ray Soft Gripper's Finger," vol. 10, no. 11, 2023.

[4] "Thermoplastic polyurethane (TPU): The Basics," Optinova. Accessed: Mar. 10, 2024. [Online]. Available: https://optinova.com/news/thermoplastic-polyurethane-tpu-the-basics/

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