2023 IEEE/ASME International Conference on
Advanced Intelligent Mechatronics (AIM)

Hysteresis Dehunting of a Tendon-Sheath Confined Space Manipulator for Fast and Precise Control

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***Abstract*—Tendon-sheath robots have several advantages for entering hazardous confined-space environments given their reduced size and weight, in addition to being intrinsically-safe when there is a risk of explosion. When teleoperated due to limited sensing in confined-space environments, backlash and stick slip friction in tendon-sheath robots cause hunting-like oscillations around the goal position. The main contributions of this work are to (1) develop an automation method that converges each joint to target values while avoiding backlash and stick slip friction and (2) apply the automation method using traded control to dehunt the teleoperation. Experimental results show the approach leads to an end effector precision of five-thousands of an inch, an order of magnitude better joint level precision than current tendon-sheath control schemes [1]. Trials of the automated method show a 57.1% reduction in completion time for a precision location task. Initial user studies (N=3) of the method shows a 38.5% reduction in user completion time compared to teleoperation with existing compensation methods.**

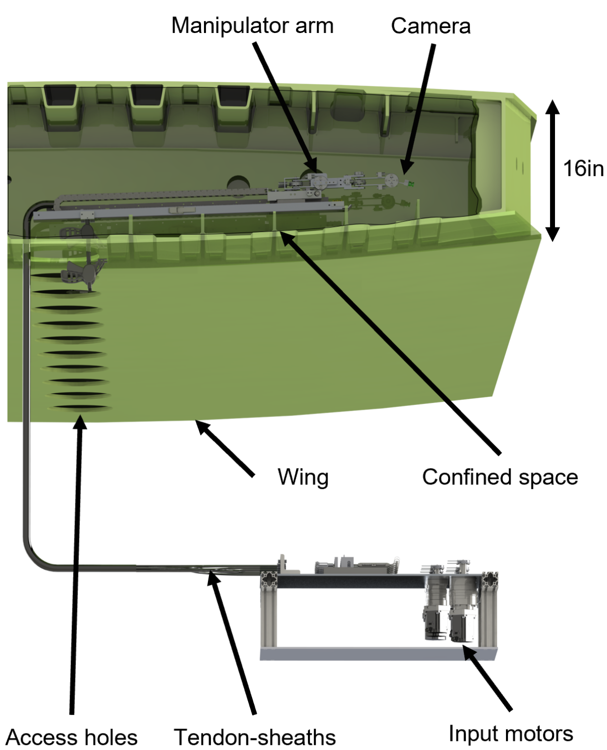

Fig. 1. Tendon-sheath confined space robot actuated by motors placed outside of wing tank. Wing sectioned for clarity.

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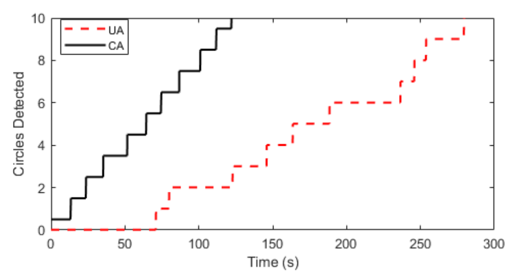
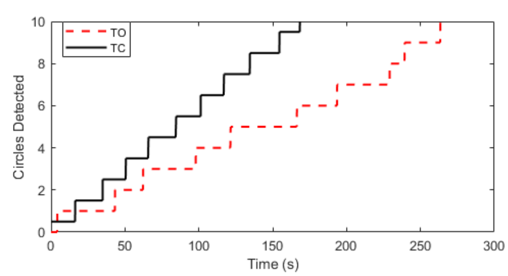
I. Results

We use a tendon-sheath manipulator installed in a confined space for trials [2] (Fig. 1). Our trial consists of either a user or automation aligning with ten goal locations arranged in a pattern similar to common confined space manufacturing tasks such as drilling. The goal locations are specified by AprilTags and a visual servo control scheme aligns with the target. In traded control (TC) and teleoperation (TO), a user provides velocity inputs with a joystick to align with a goal. During TC, the desired goal location is inferred and the user can press a button to initiate the compensated automation method. In uncompensated automation (UA) and compensated automation (CA) the system aligns with ten goal locations known a priori. Figure 2 shows time traces for trials, and we achieve an average of 57.1% and 38.5% reduction in completion times for automation and teleoperation respectively.



(a) Automated methods



(b) Teleoperated methods

Fig. 2. Fasteners inspected over time for a) compensated and uncompensated automation methods, b) traded control and teleoperation methods.

References

[1] S.-M. Yoon, W.-H. Choi, and M.-C. Lee, "Backlash compensation by smooth backlash inverse for haptic master device using cable-conduit," in *2014 14th International Conference on Control, Automation and Systems (ICCAS 2014)*, 2014, pp. 127–132.

[2] J. D. Chungbin *et al.*, "Mechanical avatar assembly and system for use in a confined space in a structure and method of using the same," united States Patent 0281102.