

BaSiL: A Tendon-Driven Beaded Spine Robot for Shape-Adaptive Locomotion

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Abstract—Body adaptation can help small robots navigate obstacles comparable to their size. We present BaSiL, a wheeled robot whose tendon-driven beaded spine combines passive compliance with active vertical and lateral bending. Coordinated body reconfiguration increases the step height climbed in all five trials from 10 mm with a rigidly constrained spine to 65 mm.

I. MOTIVATION AND DESIGN

Compliant spines can improve locomotion in bioinspired robots [1]. Combining passive deformation and active bending allows the body to respond to terrain contact and change its shape to climb obstacles. Building on beaded metamaterials [2], BaSiL consists of two rigid wheeled modules connected by a flexible spine made of rigid beads woven together with nylon thread (Fig. 1).

The 240 g robot measures $310 \times 60 \times 36$ mm, with 18 mm-radius wheels and a 90 mm-long spine made from 8 mm beads. Two motors drive the wheels; two additional motors pull and release opposing tendon pairs for vertical and lateral bending. Relaxed tendons allow passive deformation during terrain contact. This architecture combines wheel propulsion and body adaptation with four actuators.

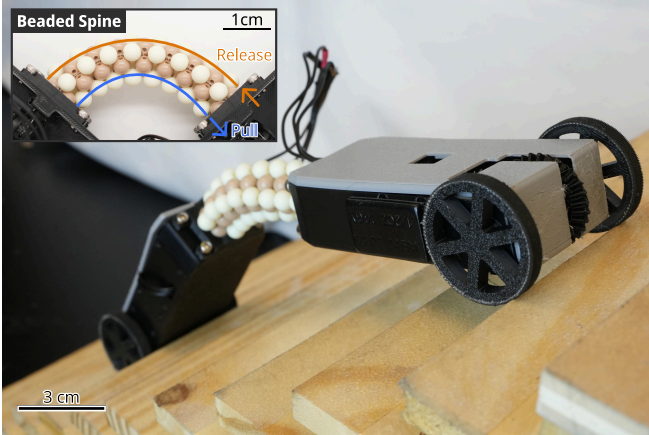


Fig. 1. BaSiL traverses a wooden staircase using its tendon-driven beaded spine. The inset illustrates bending through differential tendon pulling and release.

II. STEP-CLIMBING PERFORMANCE

We compared a rigidly constrained spine, an unactuated passive spine, and three active strategies, with five trials per step height. The active strategies used predefined open-loop

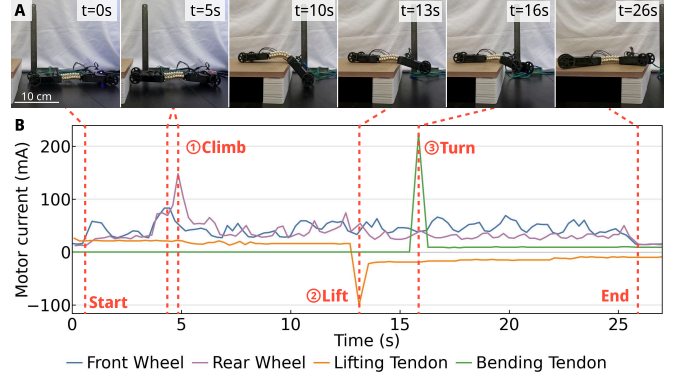


Fig. 2. Three-phase traversal of a 70 mm step. (A) Image sequence showing front-module climbing, rear-module lifting, and lateral turning. (B) Corresponding currents for the front and rear wheel motors and the lifting and bending tendon motors.

commands. Single-phase actuation bends the spine vertically to assist front-module ascent. Two-phase actuation adds a reversal of vertical bending to lift the rear module. Three-phase actuation further adds lateral bending to turn the body and complete the climb (Fig. 2).

Success required both modules to reach the upper surface. The maximum step heights climbed with a 100% success rate were 10 mm (rigid), 20 mm (passive), 35 mm (single-phase), 50 mm (two-phase), and 65 mm (three-phase).

The three-phase strategy achieved 65 mm in 5/5 trials and 70 mm in 2/5 trials, corresponding to normalized step heights h/r of 3.61 and 3.89, respectively, where h is the step height and r is the wheel radius.

III. CONCLUSIONS AND FUTURE WORK

BaSiL combines passive compliance and active body bending in a single beaded spine. Step-climbing experiments show that passive deformation improves obstacle traversal, while coordinated vertical and lateral bending further increases the traversable step height. These results demonstrate how body adaptation can extend the mobility of a wheeled robot. The current prototype relies on external power and teleoperation. Future work will integrate onboard power and sensory feedback for untethered operation and closed-loop control of spine deformation.

REFERENCES

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