Continuum Locomotion Alternative for Robotic Adaptive-Exploration (CLARA)

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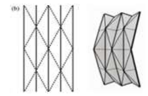
Abstract

Current forms of remote pipe inspection, such as borescopes, are limited in their maneuverability. We propose a salamander inspired soft robot as a novel pipe inspection tool that can overcome many pipe sizes, vertical pipes, tees, and bends using a variable diameter suspension mechanism. The origami body uses a Yoshimura crease pattern to create deformable cable driven bellows, enabling steering without traditional rigid mechanisms. To enable closed-loop position and velocity control, we introduce a smart motor driver PCB, useful for applications beyond this project's scope. They communicate over I2C by a custom mainboard receiving remote commands via Wi-Fi and UART from gamepad input. The system achieves 4.5" of linear compression, 1.6" of diameter range and 85.8° maximum bending angle.

Background

- Origami is a tool to create desired mechanical behavior when rigid mechanisms are insufficient
- Crease patterns produce varied behavior, such as the Yoshimura pattern which features axial compression when connected in a three-pattern module
- Salamanderbot applied this pattern with thread and motors to compress the module, climbing sharp inclines and navigating through turns



Yoshimura Fold Pattern [1]

Salamanderbot [2]

Goals and Objectives

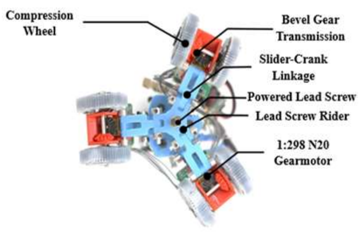
Explore the capabilities of a soft robotic origami module in the inspection and exploration of pipe networks too small, expansive, or dangerous for humans.

Design and test at least three different types of active actuators for use in the variable diameter suspension mechanism and one type of passive suspension.

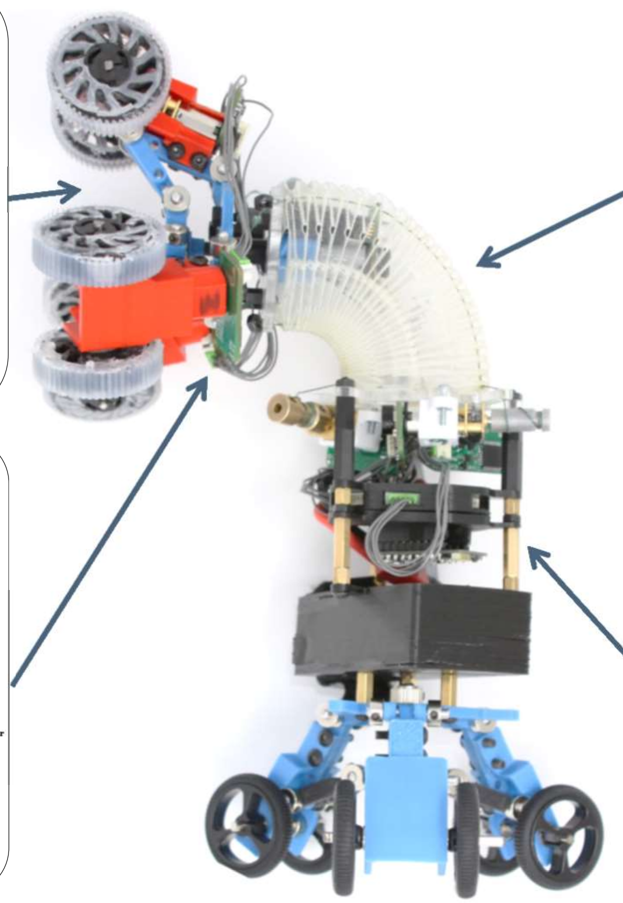
Create a more inclusive electrical schema to be applied to projects outside of CLARA through the creation of smart motor drivers capable of controlling individual N20 motors.

Develop a control architecture that allows for wireless communication of autonomous as well as teleoperated control of the module.

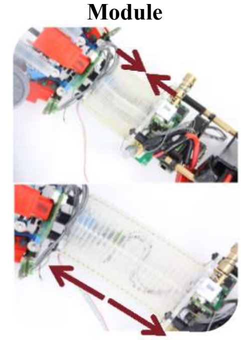
Active Variable-Diameter Suspension



Lead Screw Slider-Crank Mechanism: Compact slider-crank driven by a lead screw enables controlled diameter alteration



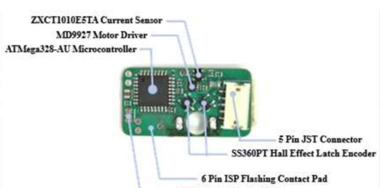
Yoshimura Continuum Module

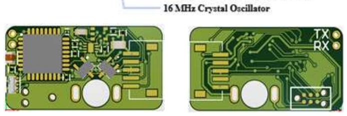


Yoshimura Origami Body: Continuously deformable cable-driven bellows

Smart Motor Driver PCB

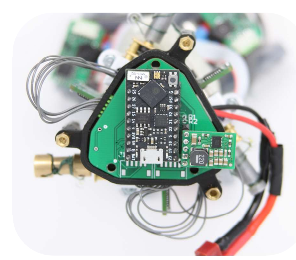
- Provides power, sensing and control with encoders, current sensors, motor drivers, and a microcontroller
- Daisy-chain compatibility using 5-pin JST connectors and I2C, providing a fully scalable system





Mainboard

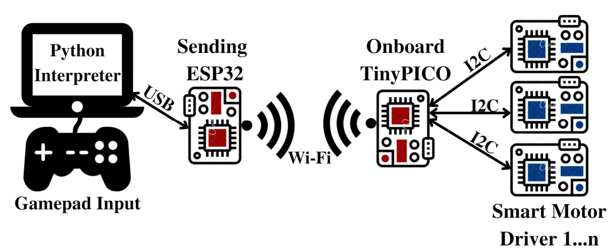
- TinyPICO (ESP32 microcontroller) enables Wi-Fi communication with ESP-NOW
- Onboard power regulation to step down 7.4V motor voltage to 3.3V for logic voltage
- Communicates with Smart Motor Drivers via I2C



Mechanical Performance

Category	Value	Units
Weight	1.1	lbs
Yoshimura Module Length	1.5 - 6.0	in
Maximum Turning Radius	85.8	deg
Effective Diameter Range	3.6- 5.2	in
Wheel Compression	0.3	in
Maximum Speed	6	in/s

Control Structure



References

[1] J. Santoso, E. H. Skorina, M. Luo, R. Yan, and C. D. Onal, "Design and analysis of an origami continuum manipulation module with torsional strength," in 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Sep. 2017, pp. 2098–2104. doi: 10.1109/IROS.2017.8206027.

[2] Y. Sun et al., "Salamanderbot: A soft-rigid composite continuum mobile robot to traverse complex environments," in 2020 IEEE International Conference on Robotics and Automation (ICRA), May 2020, pp. 2953–2959. doi 10.1109/ICRA40945.2020.9196790.