Mesh of Robots on a Pneumatic Highway (MORPH)
An Untethered, Human-Safe, Shape-Morphing Robotic Platform

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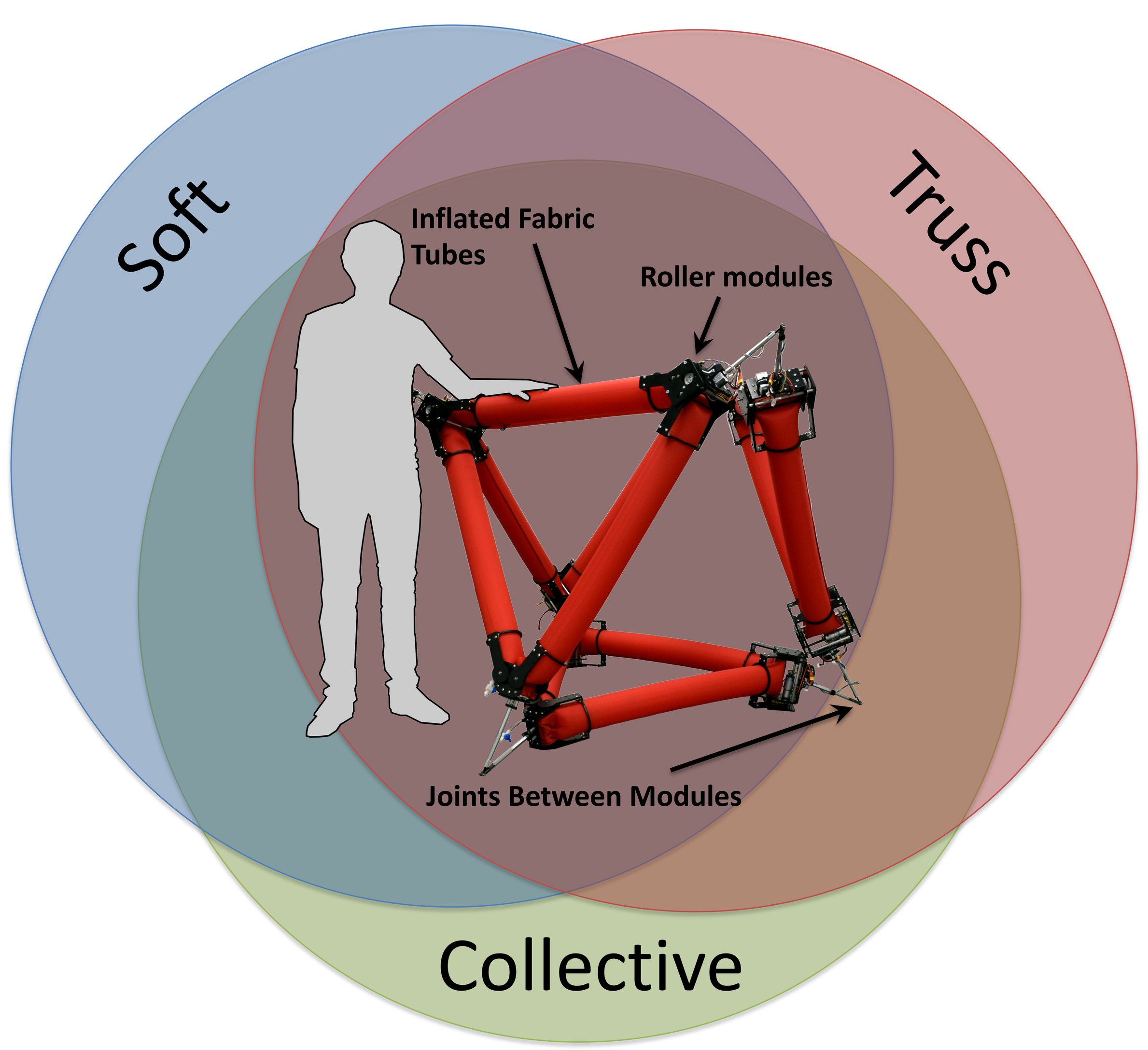
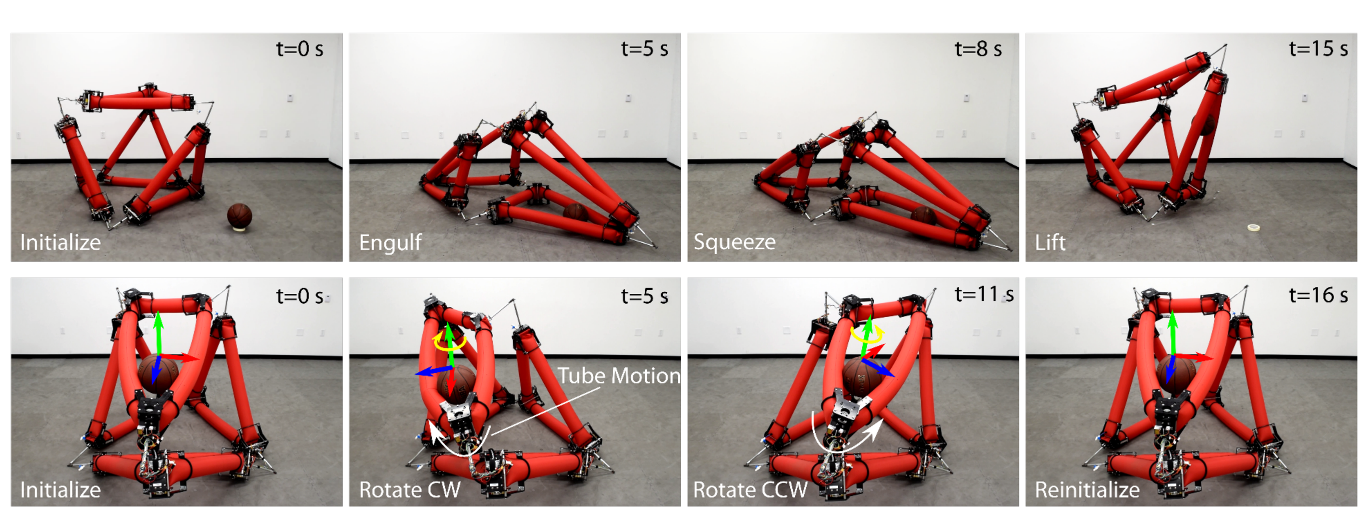
Concept

Challenge: How can we create un-tethered soft robots capable of dramatic shape change?



The MORPH draws inspiration from soft, collective, and truss-based robots, while overcoming the limitations of each.



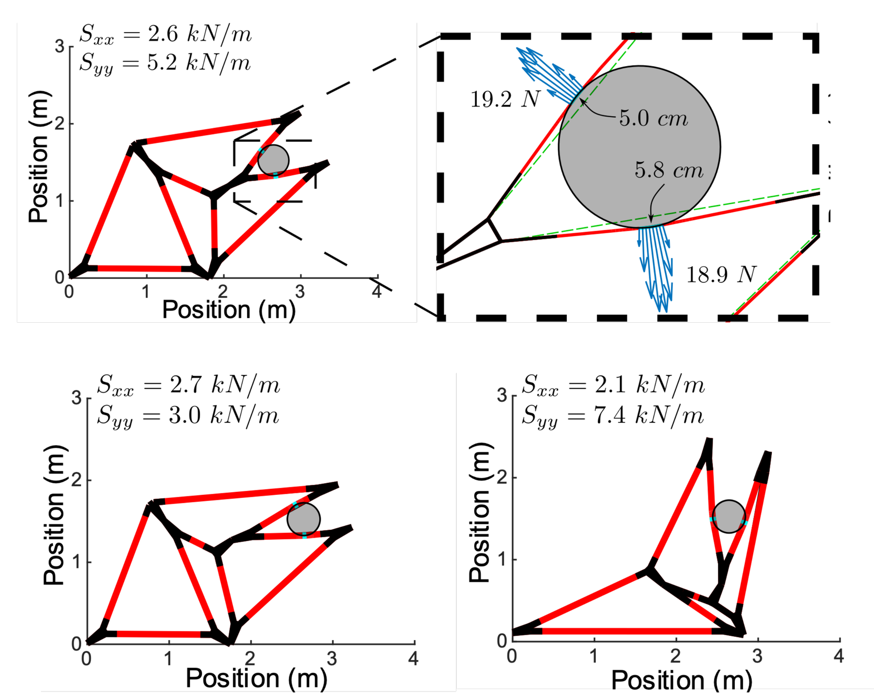
Usevitch, N. S., Hammond, Z. M., Schwager, M., Okamura, A. M., Hawkes, E. W., & Follmer, S. (2020). An untethered isoperimetric soft robot. Science Robotics

Scientific Impact

Modeling: Grasp Analysis

Compliant truss robots can grasp objects with large contact areas and even force distribution.

We use a direct stiffness model to characterize the robot and its interactions with external objects. We apply this model to a nine member, 2D, isoperimetric truss robot in different grasping configurations and compute the resulting forces, contact regions, deformation, and grasp stiffnesses.



Hammond, Z. M. & Follmer, S. "Grasp analysis and manipulation kinematics for isoperimetric truss robots." *ICRA 2021*

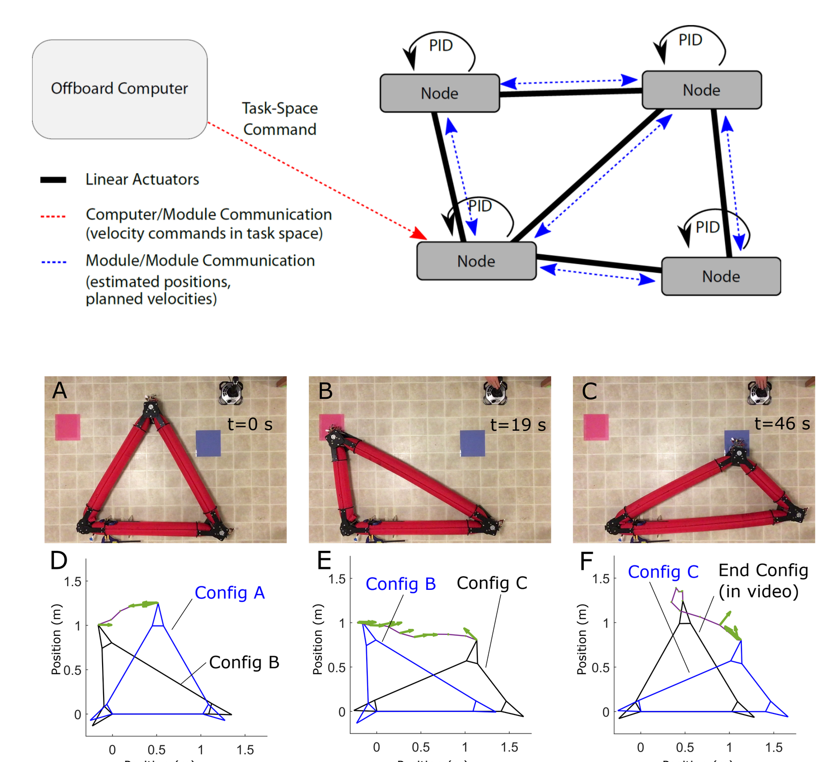
Distributed Control and Estimation for Truss Robots

Consensus ADMM enables scalable distributed state estimation and control.

Each joint passes messages with neighbors and iterates on an optimization objective.

Nodes converge to jointly optimal velocities while enforcing local constraints.

Velocities followed with local PID controller at each joint.

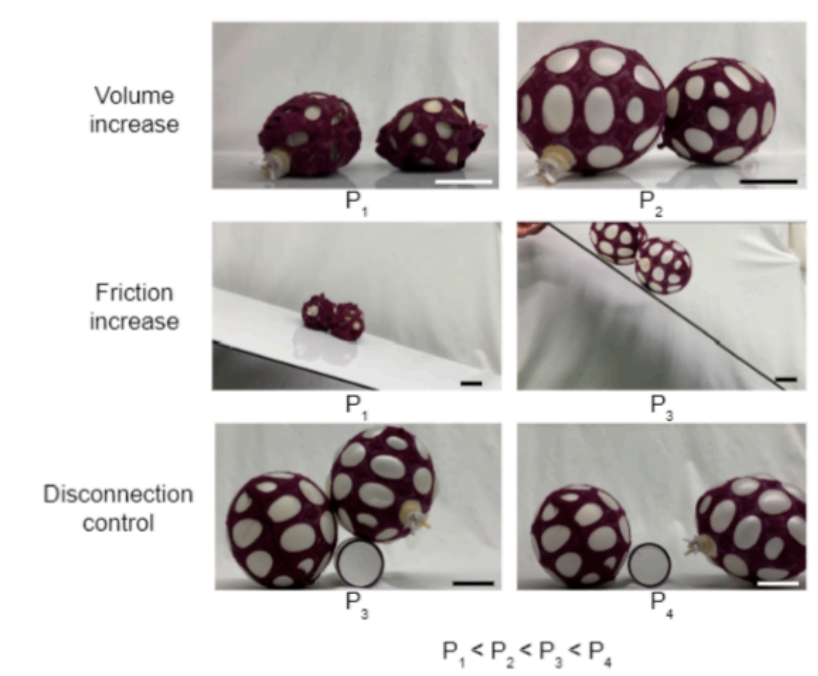


New Hardware Platforms: Soft Cellular Robots

Nodes and links of truss can be represented as size-changing spheres.

Groups of these "cellular robots" could form a collective to perform locomotion, shape change, and apply forces.

Demonstrated untethered "cells" that can change volume by 10x, vary their coefficient of friction, and control cohesion forces to connect or disconnect.



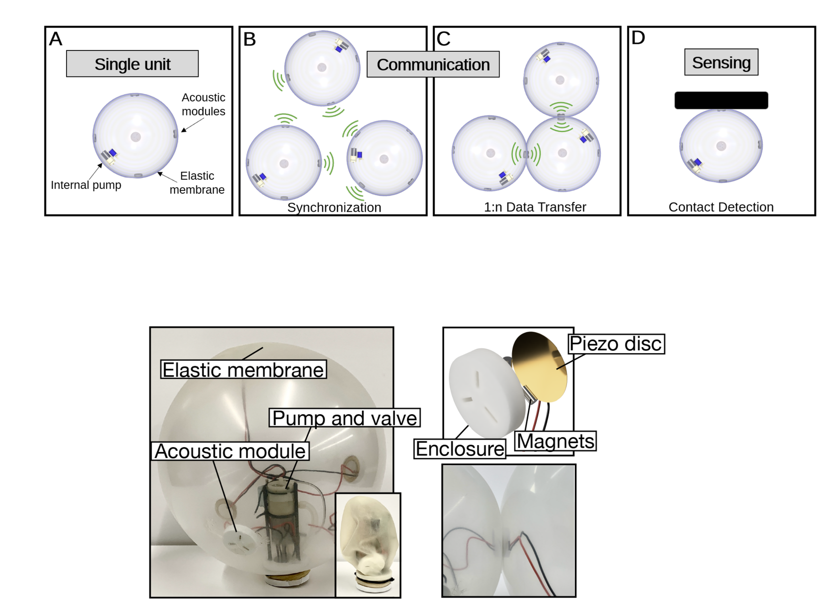
Devlin, M.R., Young, B.T., Naclerio, N.D., Haggerty, D.A. and Hawkes, E.W., An untethered soft cellular robot with variable volume, friction, and unit-to-unit cohesion. *IROS2020*.

Soft Sensing and Communication

Acoustic Sensing and Communication for Inflated Soft Robots

Multifunctional, low-cost components that take advantage of the robot's structure

Using piezoelectric discs mounted to the compliant skin of soft cellular robots, we demonstrated ability to synchronize motion among units, pass information for coordinated crawling, and sense local contact

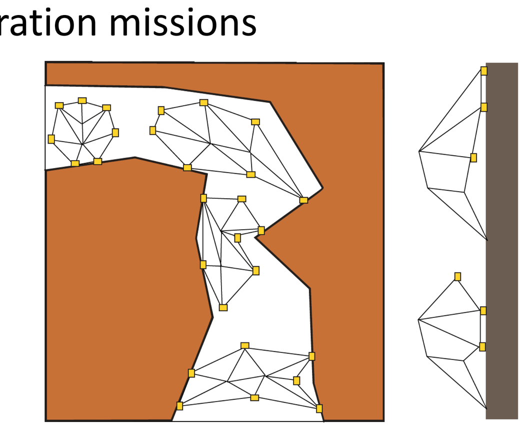


D. S. Drew, M. Devlin, E. Hawkes, and S. Follmer, "Acoustic Communication and Sensing for Inflatable Modular Soft Robots," *ICRA2021*

Broader Impact

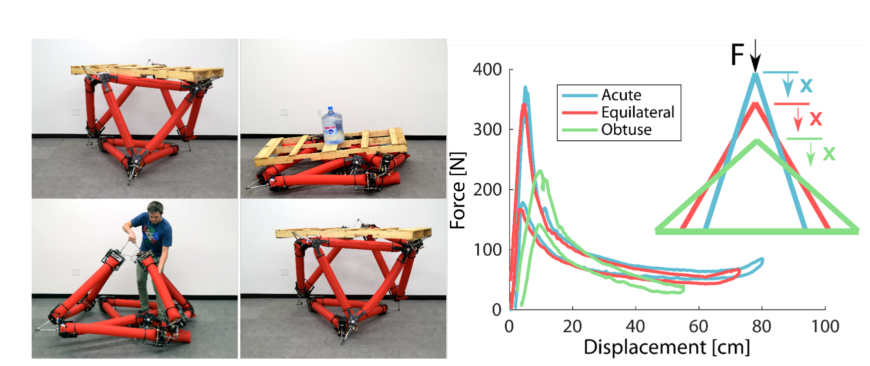
Rough Terrain Locomotion

We will leverage the shape-changing ability to allow the robot to move over rough terrain in search and rescue missions and planetary exploration missions



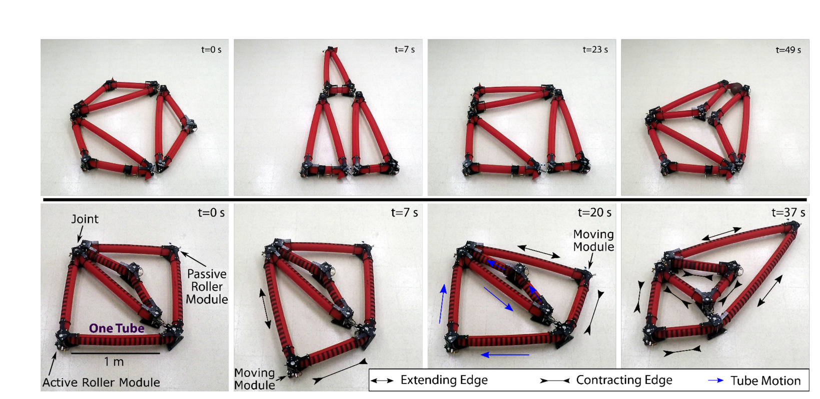
Human-safe interaction

The compliant structure limits the force that can be output. We will use the robot to assist humans in everyday tasks.



Education

Modularity, reconfigurability and inherent safety make the MORPH system a valuable educational tool



Outreach

Our robotic platform was featured by the YouTube Science Channel Veritasium, to help explain the benefits of Soft Robots, and has been viewed more than 2 million times.

2021 NRI & FRR Principal Investigators' Meeting
March 10-12, 2021

Award ID#: 1925030 and 1925373