

Vine Robots

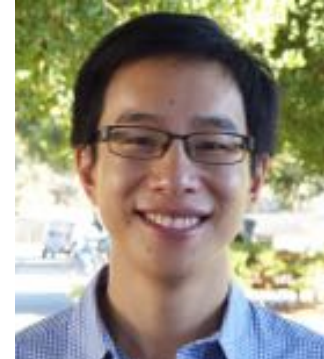
Achieving Mobility and Construction by Growth

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Elliot Hawkes, subcontract PI
(UCSB)



Jonathan Fan, co-PI
(Stanford)

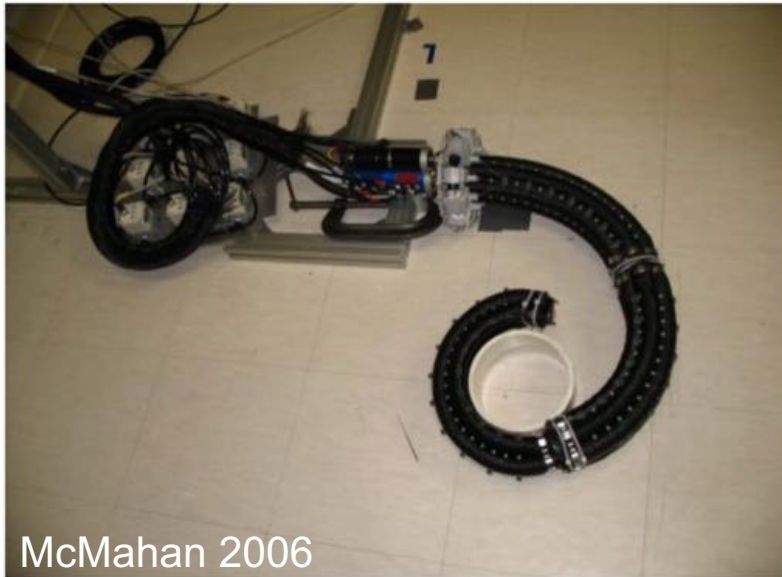


Sean Follmer, co-PI
(Stanford)

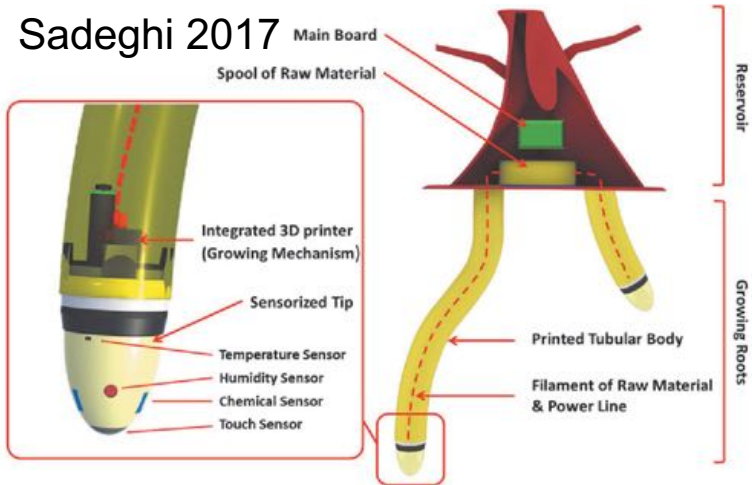
Continuum and Growing Robots



Marchese 2016



McMahan 2006



Sadeghi 2017



(1)



(2)



(3)



(4)

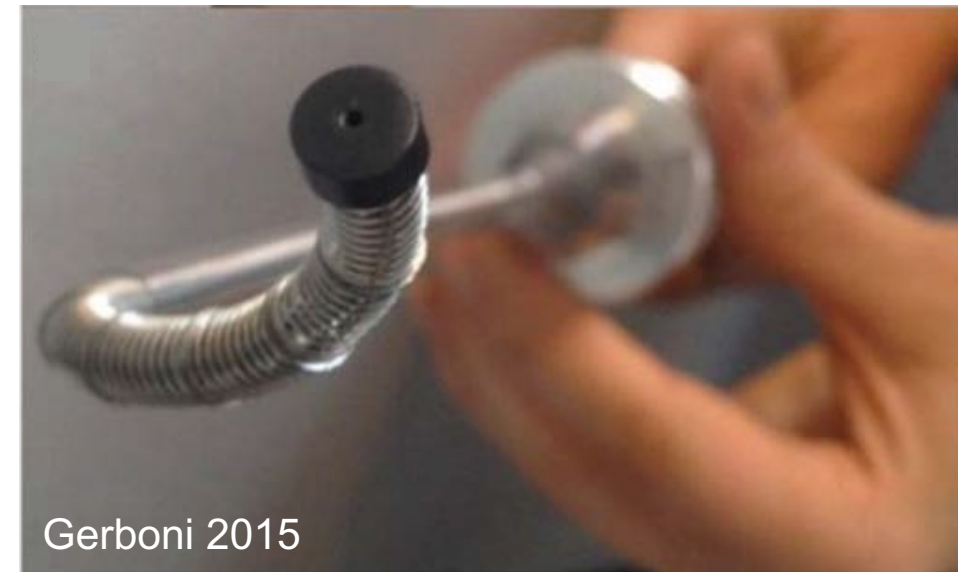
Tsukagoshi 2011



Starke 2017



Rucker 2011



Gerboni 2015

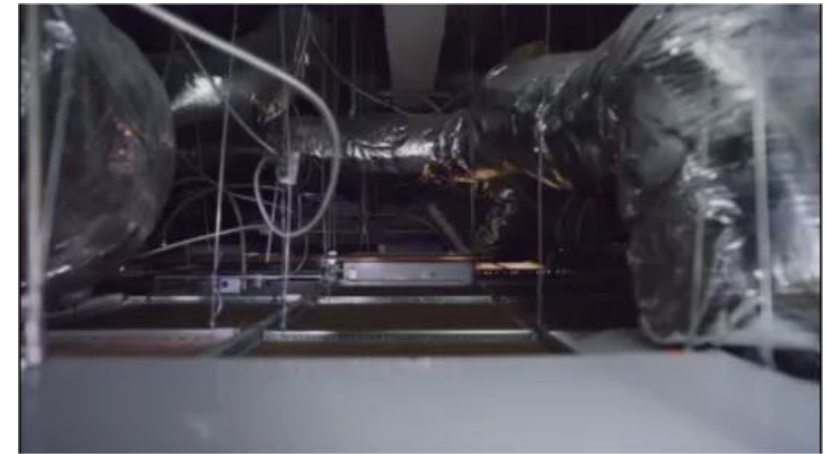
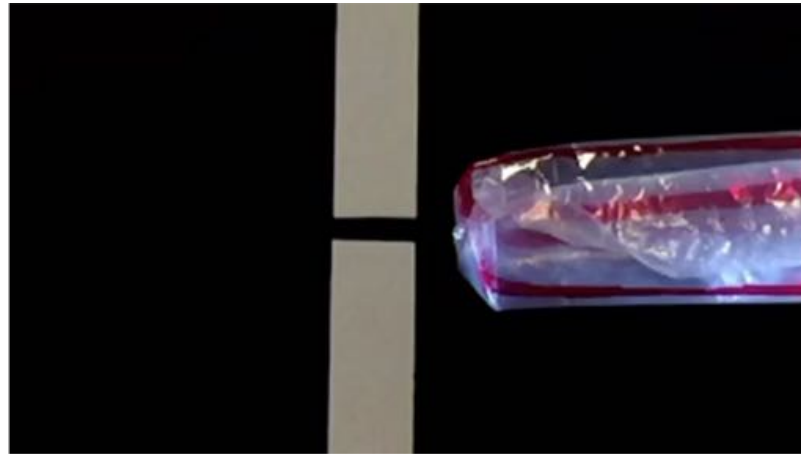
Soft Growing Robots



E. W. Hawkes, L. H. Blumenschein, J. D. Greer and A. M. Okamura. A soft robot that navigates its environment through growth. *Science Robotics*, 2(8):eaan3028, 2017.

Question: How do you steer a growing robot?

Answer 1: You don't!

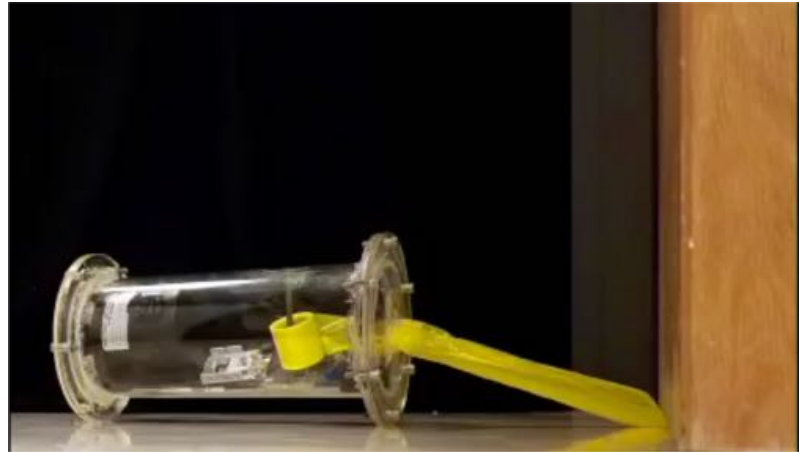
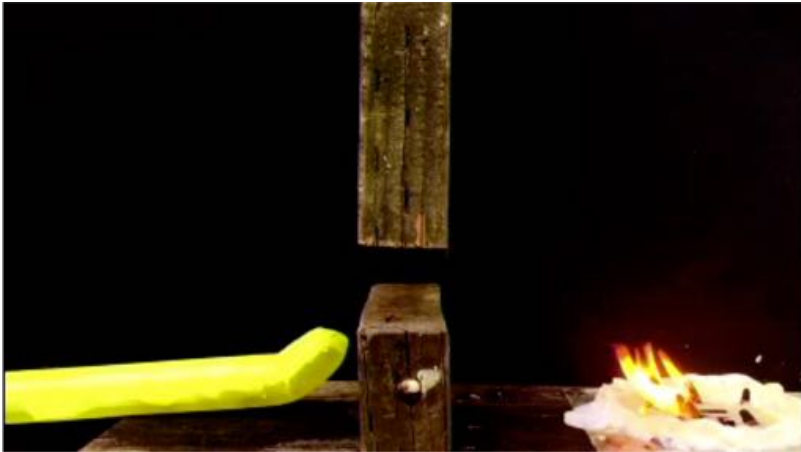


E. W. Hawkes, L. H. Blumenschein, J. D. Greer and A. M. Okamura. A soft robot that navigates its environment through growth. **Science Robotics**, 2(8):eaan3028, **2017**.

N. Naclerio, D. Goldman, E. W. Hawkes. Soft Robotic Burrowing Device with Tip-Extension and Granular Fluidization. **IROS 2018**.

Question: How do you steer a growing robot?

Answer 2: Pre-form it

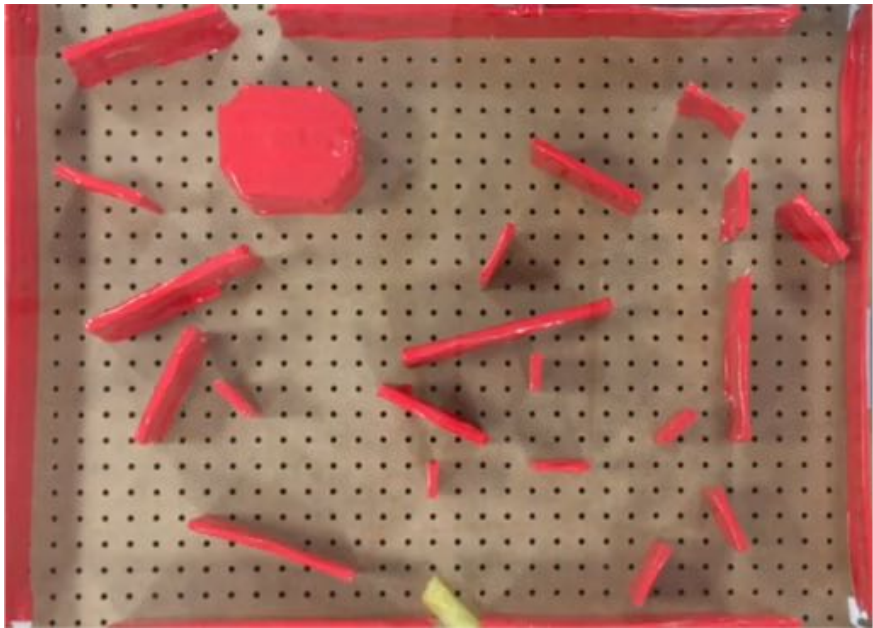


Design and assembly instructions
for pre-formed vine robots:
VineRobots.org



Question: How do you steer a growing robot?

Answer 3: Use the environment to help



J. D. Greer, L. H. Blumenschein, A. M. Okamura, E. W. Hawkes. Obstacle-Aided Navigation of a Soft Growing Robot. **ICRA 2018**.

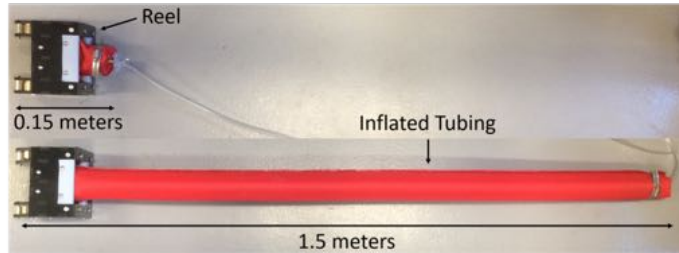
J. D. Greer, L. H. Blumenschein, R. Alterovitz, A. M. Okamura, E. W. Hawkes. Design and Path Planning for Obstacle-Aided Navigation of Soft Growing Robots. **In preparation**.

N. Naclerio, E. W. Hawkes. **In preparation**.

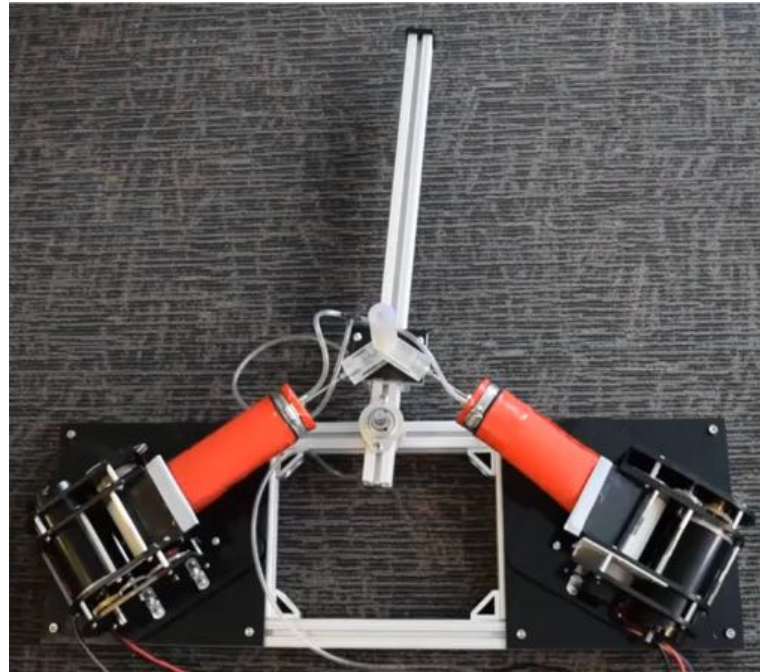
Question: How do you steer a growing robot?

Answer 4: Network them (Pneumatic Reel Actuators)

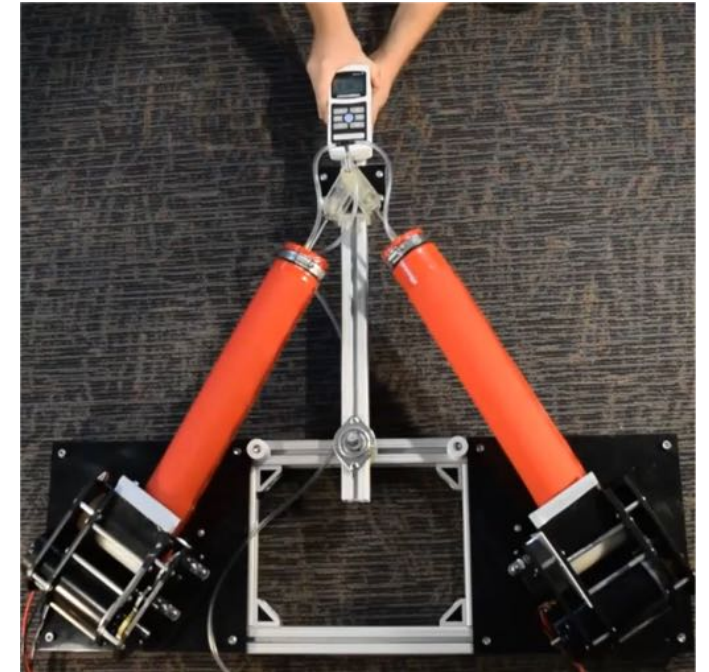
Single PRA



Networked PRA



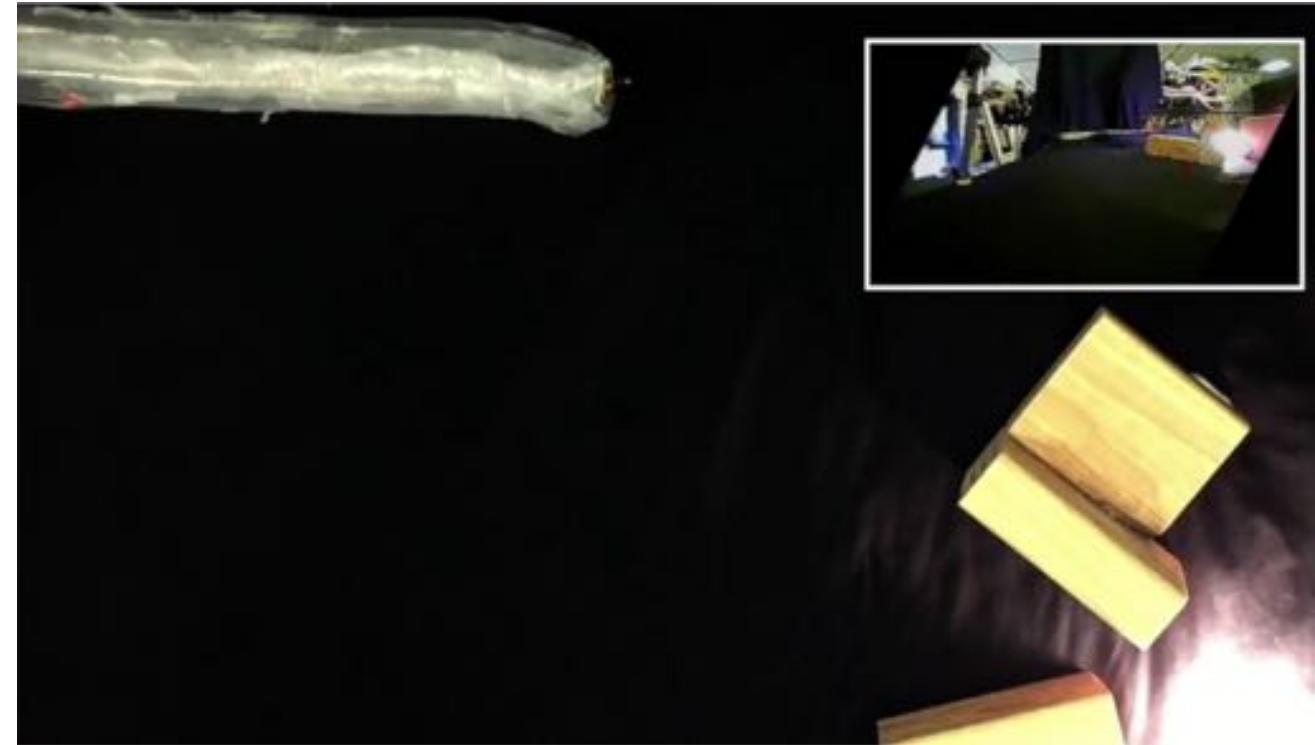
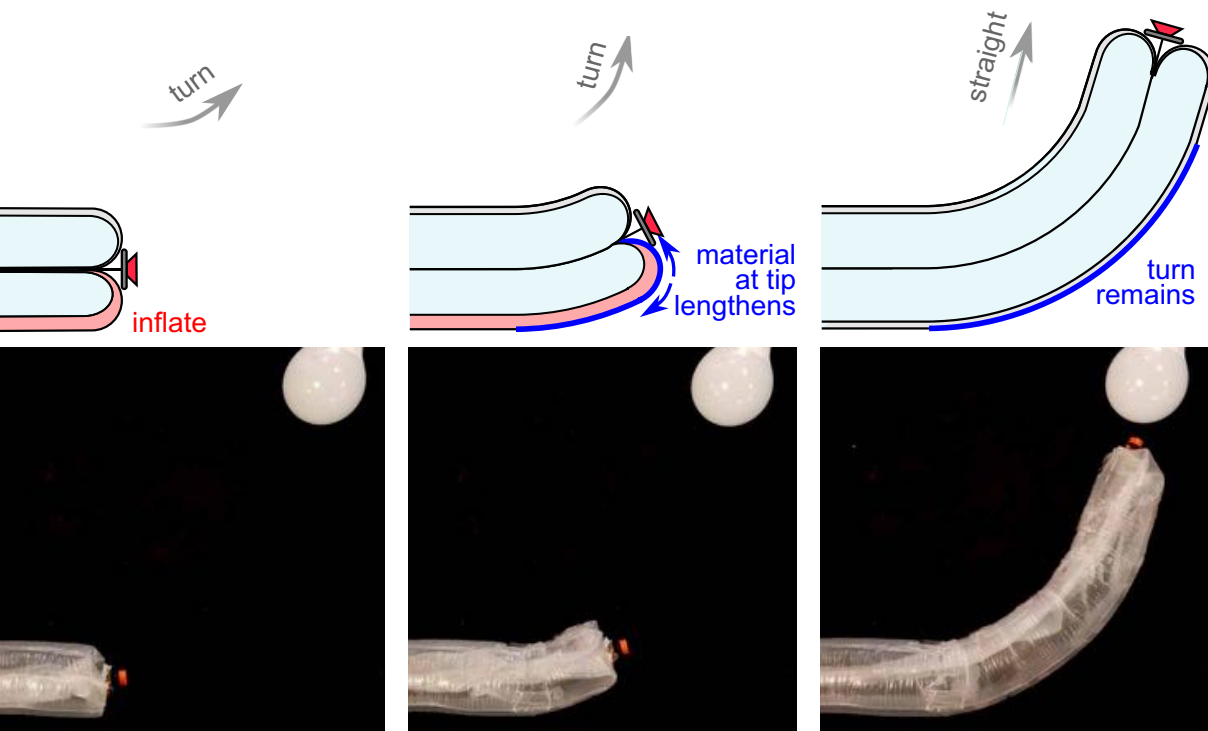
Controllable Stiffness



Z. Hammond, E. W. Hawkes, N. S. Usevitch, and S. Follmer. Pneumatic Reel Actuator: Design, modeling, and implementation. **ICRA 2017**.

Question: How do you steer a growing robot?

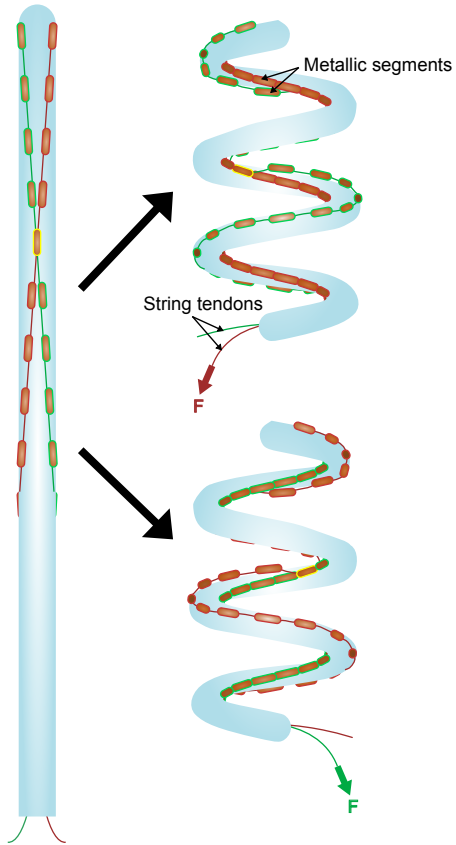
Answer 5: Locally lengthen material on one side (non-reversible)



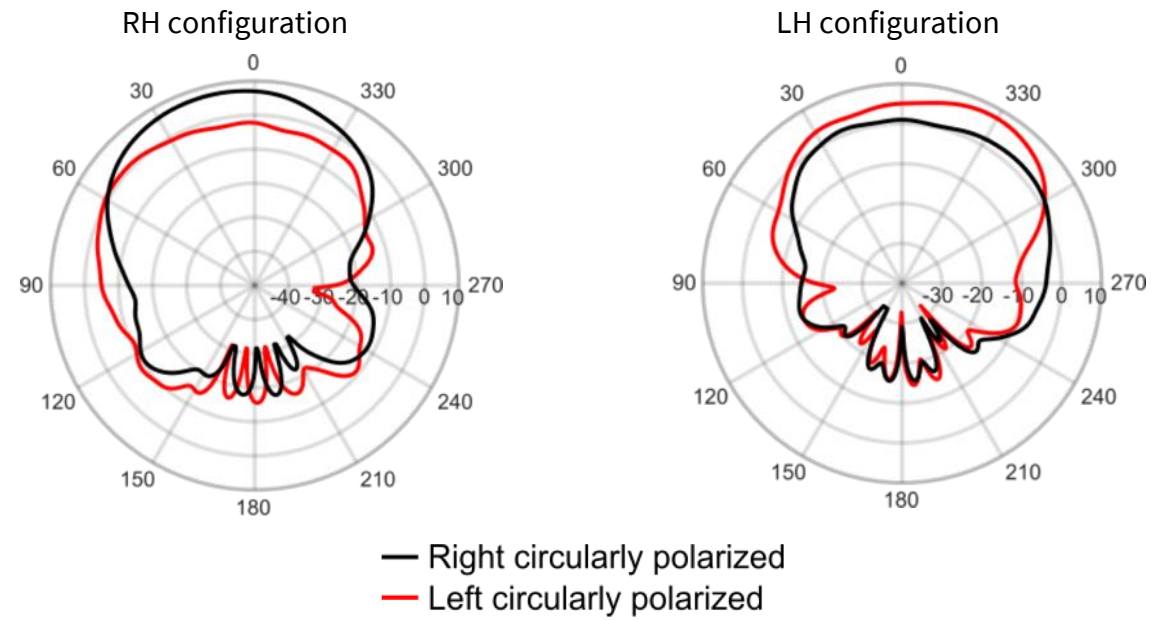
E. W. Hawkes, L. H. Blumenschein, J. D. Greer and A. M. Okamura. A soft robot that navigates its environment through growth. **Science Robotics**, 2(8):eaan3028, 2017.

Question: How do you steer a growing robot?

Answer 6: Uniformly shorten one side (reversible w/ pull strings)



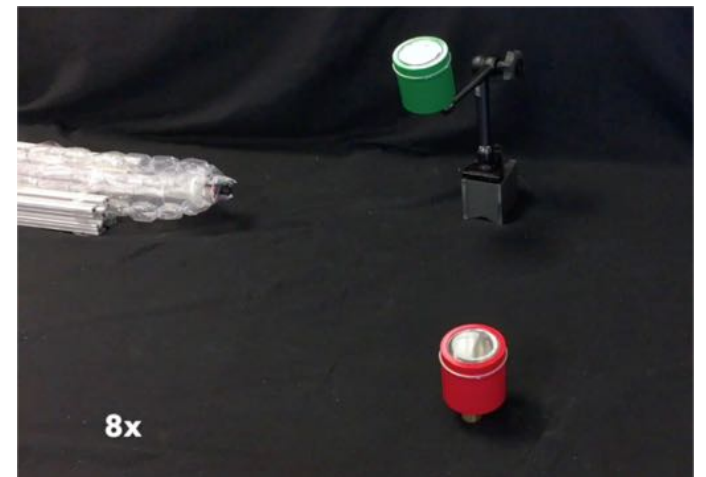
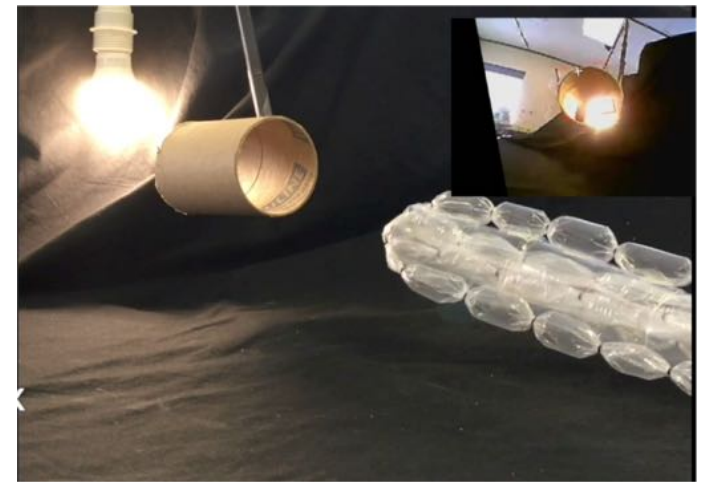
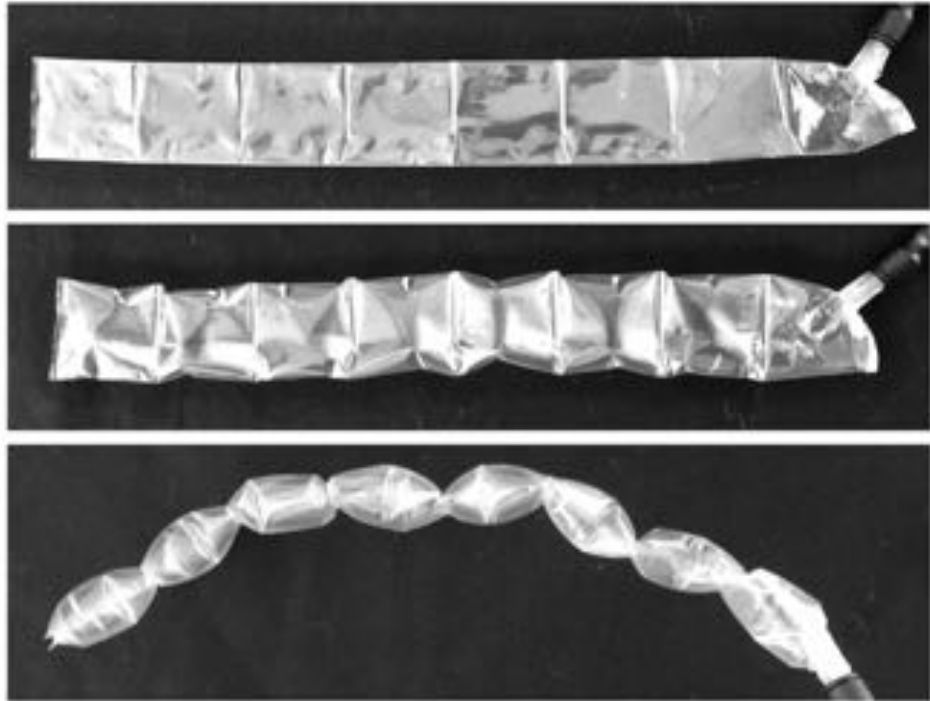
Example of chirality switching of helical antenna:
Switching handedness changes the antenna's circular polarization.



L. H. Blumenschein, N. S. Usevitch, B. Do, E. W. Hawkes, A. M. Okamura. Helical actuation on a soft inflated robot body. **RoboSoft 2018**.

Question: How do you steer a growing robot?

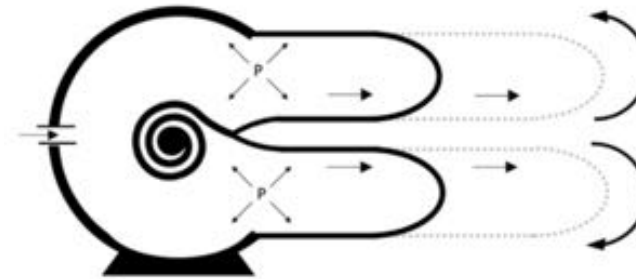
Answer 7: Uniformly shorten one side (reversible with pouches)



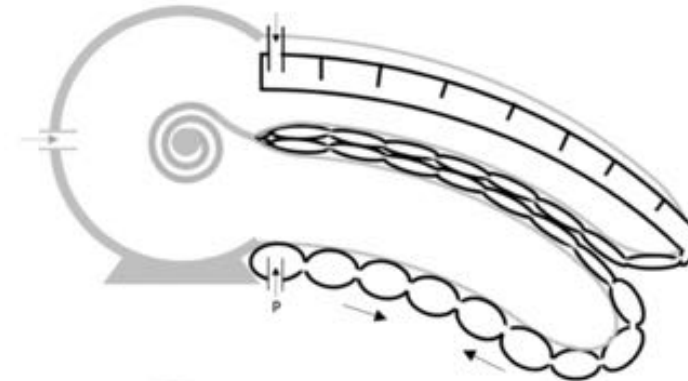
J. D. Greer, T. K. Morimoto, A. M. Okamura, and E. W. Hawkes. Series Pneumatic Artificial Muscles (sPAMs) and Application to a Soft Continuum Robot. **ICRA 2017**. A Soft, Steerable Continuum Robot that Grows via Tip Extension. **Soft Robotics, in press**.

Long Teleoperated Vine Robot

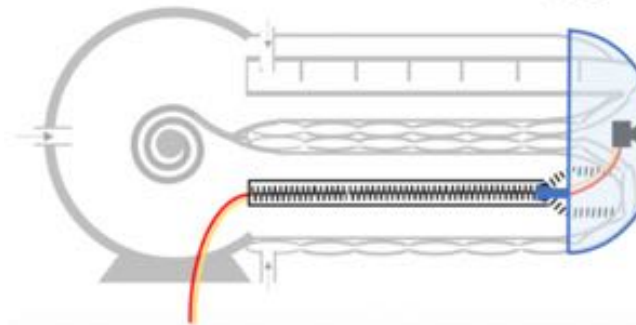
Growth to arbitrarily long lengths



Teleoperated steering using series pouch motors



Mounting of wired camera at tip using hard cap and zipper pocket

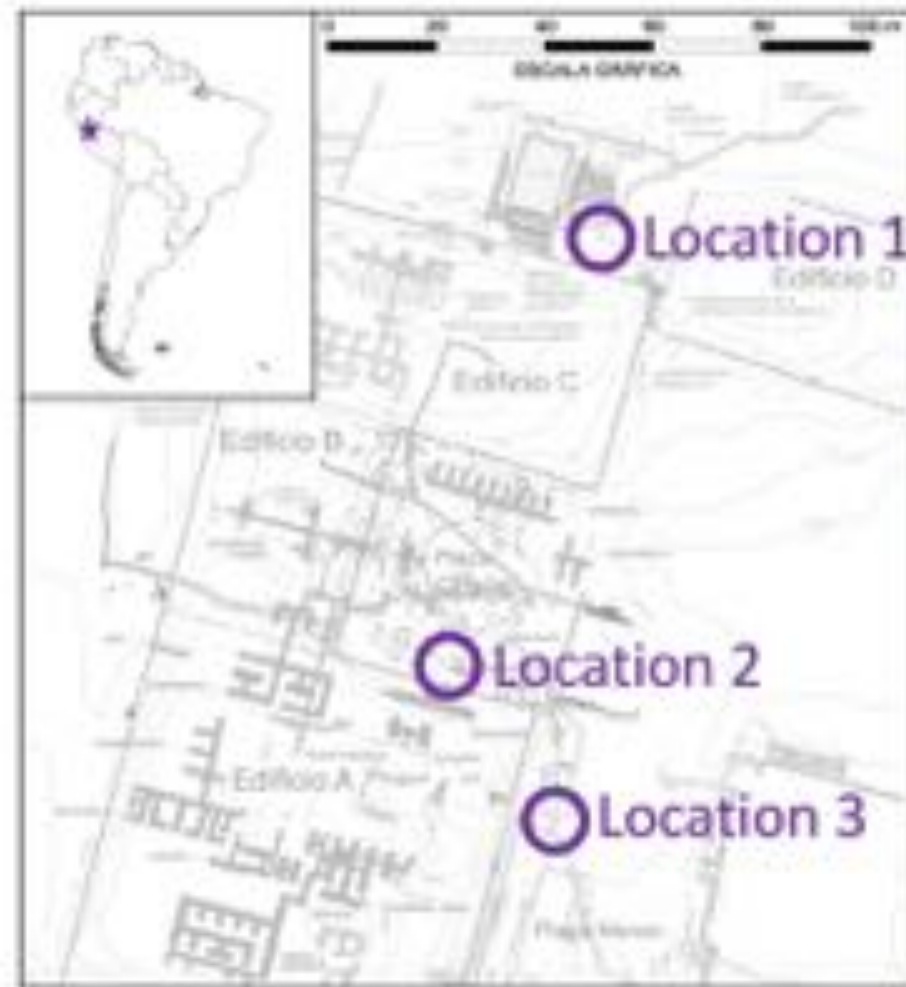


Long Teleoperated Vine Robot



Demonstrated at RoboSoft 2018 Soft Robot Navigation Competition and WIRED 25's "Robot Petting Zoo"

Archeology Expedition (Chavin, Peru, July 2018)



Location 1



Location 2



Location 3



Simulations courtesy of Jee-Hwan Ryu's group (KoreaTech)

Thank You

See our interactive **vine robot demonstration** and this **video** about the archeological expedition at **Poster #1**

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Nicholas Naclerio
Javier Reyna Zepeda
Nathan Usevitch



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Stanford
University