NRI: Liquid-Solid Metal for Embodied Intelligence in Semi-Soft, Human-Collaborative Robots

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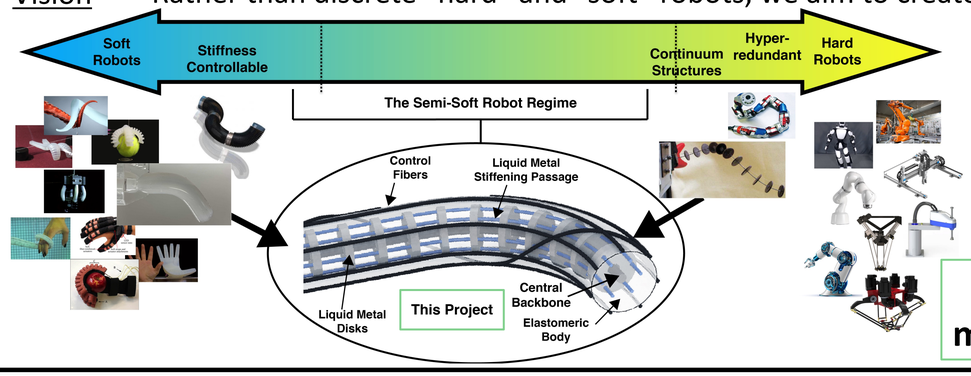
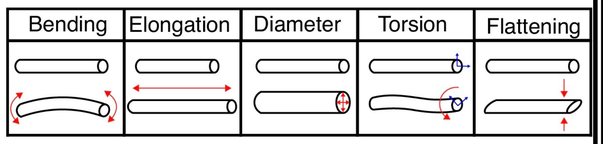
Vision

Rather than discrete "hard" and "soft" robots, we aim to create a **"semi-soft"** robot in the center of this spectrum.



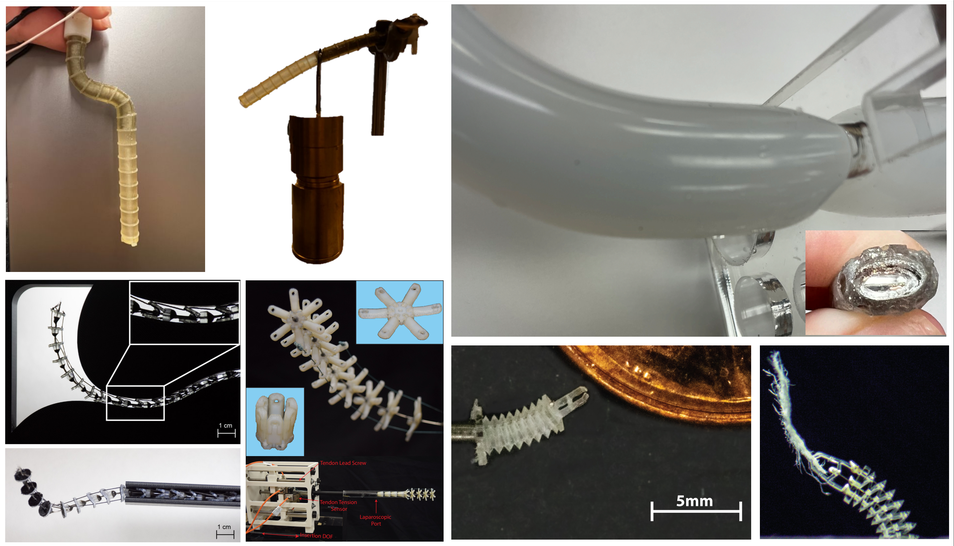
Rod mechanics affords several modes of deformation for rod-like flexible robots, which usually exist independently.

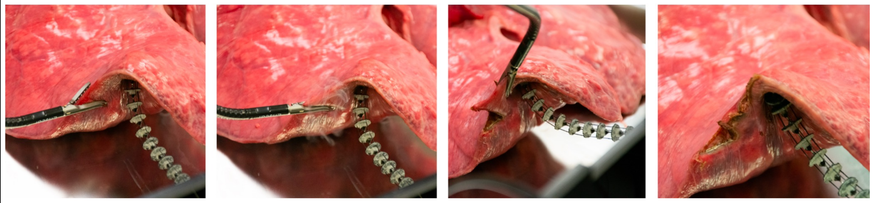


Our goal is to enable these **multimodal deformations in a single semi-soft robot.**

Design and Modelling

- **Liquid Metal Alloy (LMA)** as internal stiffness control channels and solidifiable support structures in an **elastomeric substrate**
- **Curved control fibers** to enable the full set of rod deformation modes
- **Cosserat Rod and machine learning** modeling
- **Rigid-flexible material integration** for scaling in various dimensions[4,5,6]

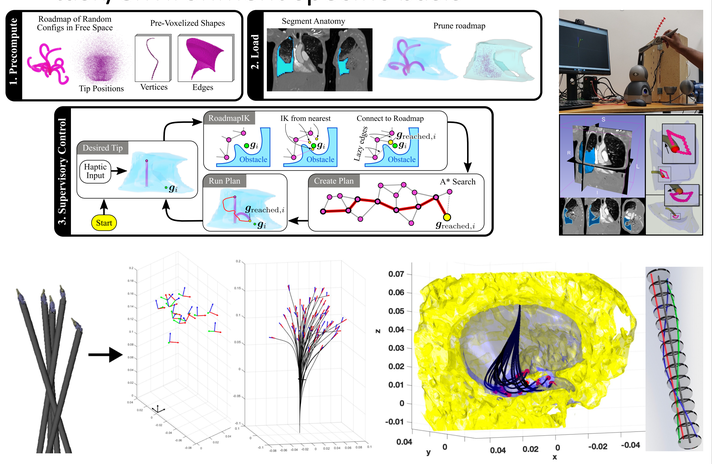




[4]M. Rox, D. S. Esser, M. E. Smith, T. E. Ertop, M. Emerson, F. Maldonado, E. A. Gillaspie, A. Kuntz, R. J. Webster III, "Toward Continuum Robot Tentacles for Lung Interventions: Exploring Folding Support Disks," *IEEE Robotics and Automation Letters*, 2023.
[5]M. E. Smith, D. S. Esser, M. Rox, A. Kuntz, R. J. Webster III, "A Radial Folding Mechanism to Enable Surgical Continuum Manipulators to Fit Through Smaller Ports," *International Symposium on Medical Robotics (ISMR)*, 2023.
[6]A. Leavitt, R. Lam, N. C. Taylor, D. S. Drew, A. Kuntz, "Toward a Millimeter-Scale Tendon-Driven Continuum Wrist with Integrated Gripper for Microsurgical Applications," *The Hamlyn Symposium on Medical Robotics*, 2023.

Control, Planning, and Design Optimization

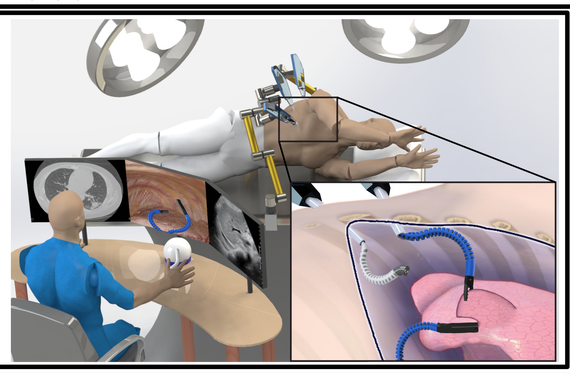
- Accurate tip control of the robot and the ability to follow desired trajectories via **resolved-rates and model predictive control**
- Supervisory control via **fast motion planning**[1]
- Context-dependent surgical sub-task automation via **learning from demonstration**[2]
- **Computational design optimization** on a task/environment specific basis[3]



[1]M. Bentley, C. Rucker, A. Kuntz, "Interactive-Rate Supervisory Control for Arbitrarily-Routed Multitendon Robots via Motion Planning," *IEEE Access*, vol. 10, pp. 80999-81019, 2022.
[2]Y. Huang, M. Bentley, T. Hermans, A. Kuntz, "Toward Learning Context-Dependent Tasks from Demonstration for Tendon-Driven Surgical Robots," *International Symposium on Medical Robotics (ISMR)*, 2021, pp. 1-7.
[3]M. Rox, A. Copinga, R. P. Naftel, R. J. Webster III, A. Kuntz, "Toward Targeted Therapy in the Brain by Leveraging Screw-Tip Soft Magnetically Steerable Needles," *The Hamlyn Symposium on Medical Robotics*, 2022.
Multiple other publications under review

Broader Impact

- Aim to **reduce the invasiveness of surgical procedures** associated with Video Assisted Thoracoscopic Surgery (VATS), e.g., surgical biopsy of lung tumors.
- 150,000 people require surgical biopsy but, due in part to its risk, **83% of these patients (124,500 per year in the USA alone) do not receive it.**
- Reducing invasiveness via a semi-soft robot may enable many more patients to have urgently needed surgical lung biopsy in the future and improve patient outcomes.



Outreach and Education

- Aspects have been incorporated as a section into a **medical robotics graduate course** at the UofU
- Outreach at **high school** events in Salt Lake City, with additional **K-12 outreach** planned in SLC and Nashville, TN
- This project has to-date supported multiple PhD students and multiple undergraduate student researchers

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

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