Achieving Variable Impedance in Flexible Robots Using Jamming

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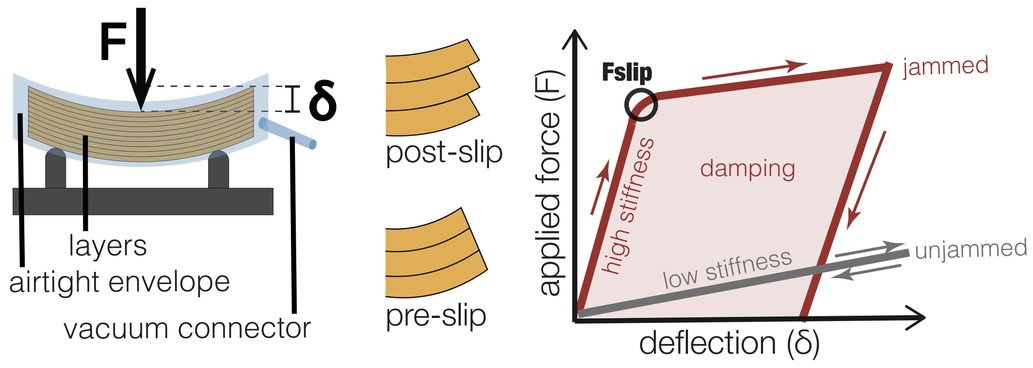
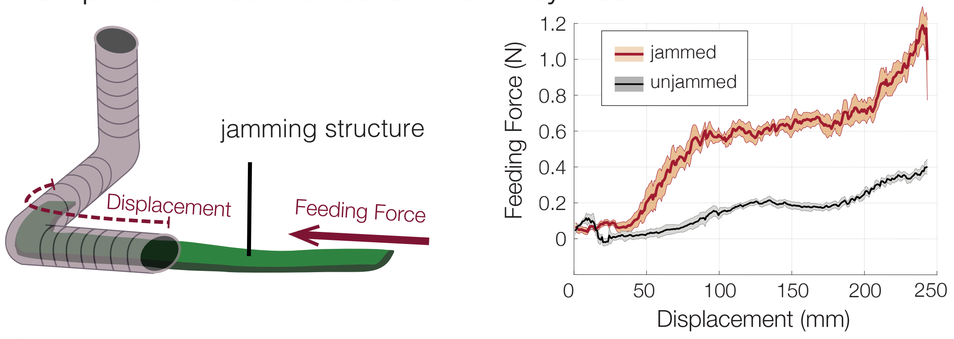
Fundamental Behavior

A jamming structure typically consists of a collection of elements that has a low overall stiffness and damping, but when a pressure gradient (e.g., a vacuum) is applied, kinematic and frictional coupling increase, resulting in dramatically augmented mechanical properties .

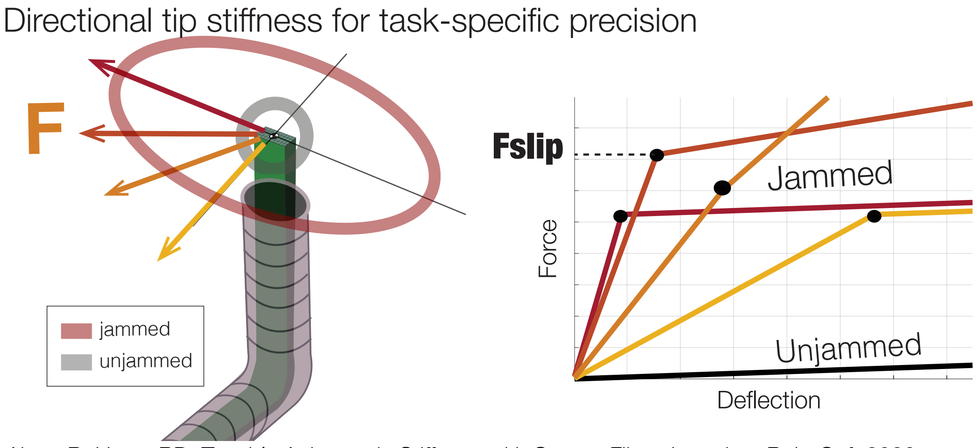


Square Fiber Jamming for Anisotropic Stiffness Control

Compliance in both directions for easy insertion



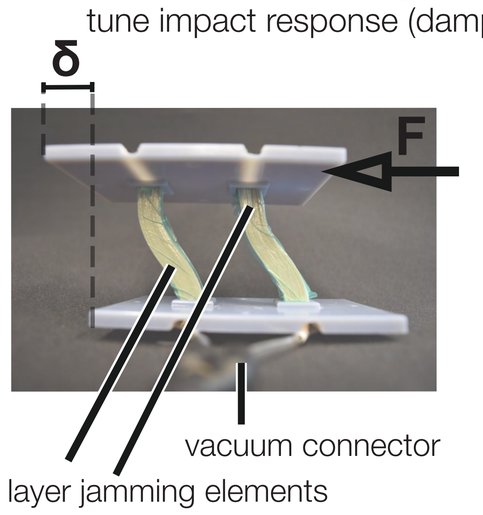
Directional tip stiffness for task-specific precision

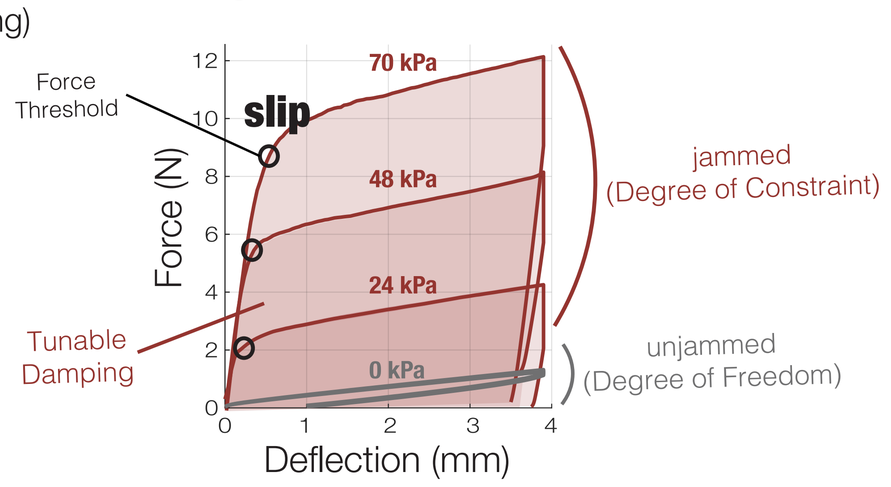


Aktaş B, Howe RD. Tunable Anisotropic Stiffness with Square Fiber Jamming, RoboSoft 2020

Flexures Using Layer Jamming

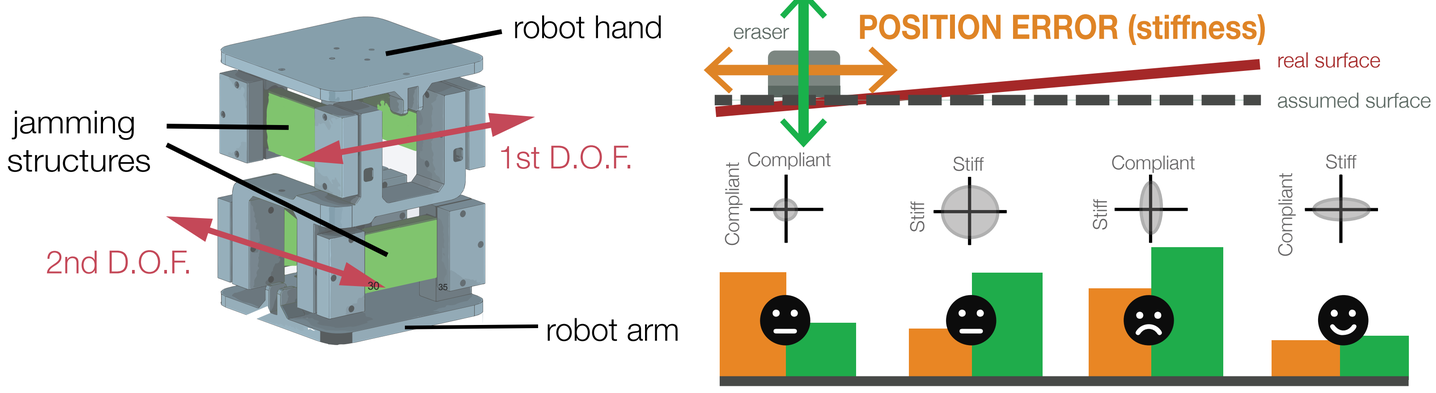
- Flexures provide precise motion control without friction or wear.
- Variable impedance mechanisms enable adaptable and robust interactions with the environment.
- Jamming-based flexures combine the advantages of both, resulting in flexure mechanisms with the versatility to:
  - transition between degrees of freedom and degrees of constraint
  - tune impact response (damping)





Jamming-Based Tunable Impedance Robot Wrist

Jamming-based flexures are particularly promising for ***modulating passive impedance*** during contact tasks. ***Compliance (i.e. low stiffness) can minimize unwanted forces*** generated by positioning errors and avoid high impact forces during tasks such as contour tracking, assembly operations, and human-robot interaction. On the other hand, ***high stiffness can enable accurate and fast motion control***. The ability to vary stiffness in response to changing task requirements can thus simplify robot control and enhance performance in a wide range of tasks.

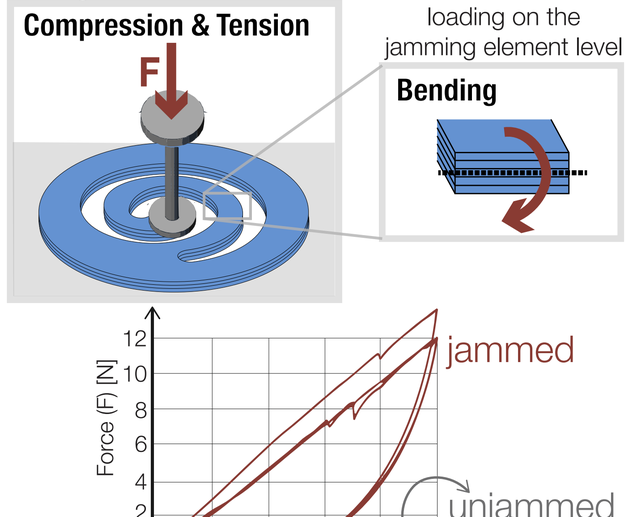


Aktaş B, Howe RD. "Flexure Mechanisms with Variable Stiffness and Damping Using Layer Jamming." IROS 2019.

Design Space of Jamming for Robotics

Analyzing the performance of different jamming media under different loading conditions lead us to a guideline to designing the right jamming structure for the right task. It also paves the way for new structure designs which leverage structural morphology to map from the loading conditions of a given task to the loading conditions of the constituent jamming elements which give the best performance.

Jamming Media	Loading Conditions: Tension	Compression	Shear	Bending
Grains (3D decomposition)	vacuum	kinematic	kinematic	vacuum kinematic
Fibers (3D decomposition)	vacuum / vacuum	kinematic / bulk	kinematic / frictional	vacuum kinematic / frictional
Layers (3D decomposition)	vacuum / bulk	bulk / bulk	frictional / bulk	frictional / bulk



Broader Impact

Scientific Community

A tutorial titled “Jamming in Robotics: From Fundamental Building Blocks to Robotic Applications” is scheduled for ICRA 2020, Paris.
https://projects.iq.harvard.edu/jamming-tutorial

STEM Education

Hands-on fabrication workshops for highschool and middle school students
“Robot Empathy Toolkit” to demonstrate the importance of variable stiffness for robot manipulation tasks

Interdisciplinary Community

Interactive art exhibitions using jamming structures
Lecture at ArtTechPsyche Symposium

2020 National Robotics Initiative (NRI) Principal Investigators’ Meeting

February 27-28, 2020 | Arlington, Virginia

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