SiMPLeR: A Series-Elastic Manipulator with Passive Variable Stiffness for Legged Robots

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Overview

Introduction

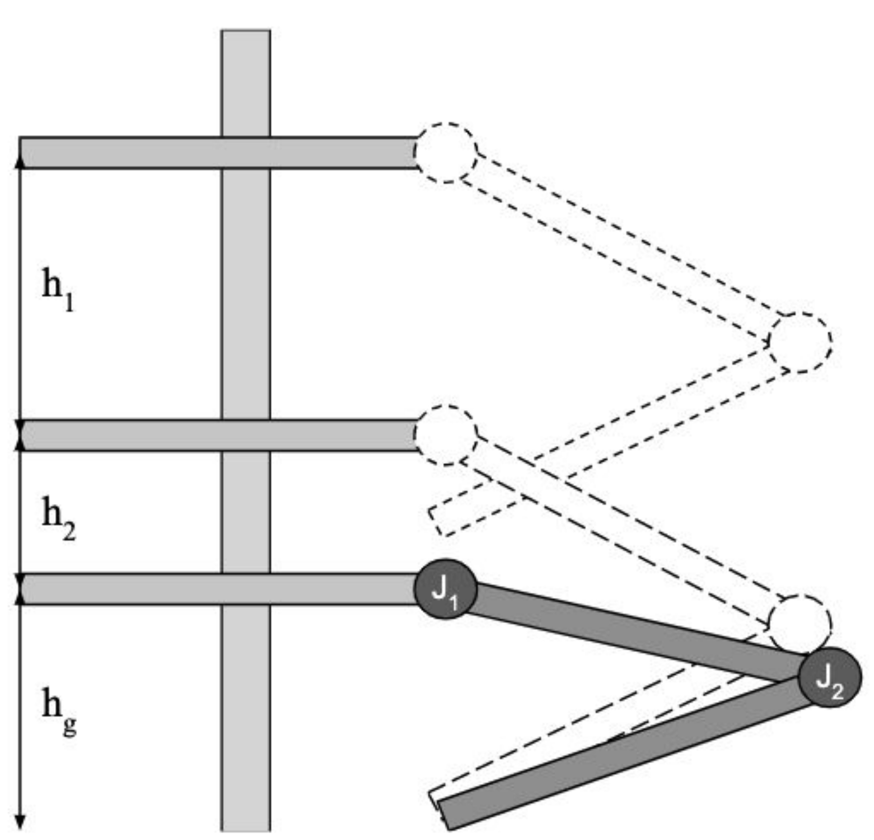
- Robots in collaborative environments require compliance to safely interact with objects and humans around them
- Compliance is achieved in actuators through either passive or active compliance; passive compliance reacts quicker and allows for energy storage
- In legged robots, variable stiffness in legs is highly desired especially in mimicking animal behavior.

Related Work

- Previous variable stiffness actuators (VSAs) lack precision, endure high energy cost, and are complex.
- Our design addresses the complexity and cost of these previous designs by using torsion springs. Our key contribution is the simplicity and versatility of our design.

Problem Definition

- We desire a compliant actuator composed of a controllable motor angle and an elastic element linking the motor and joint with controllable stiffness.

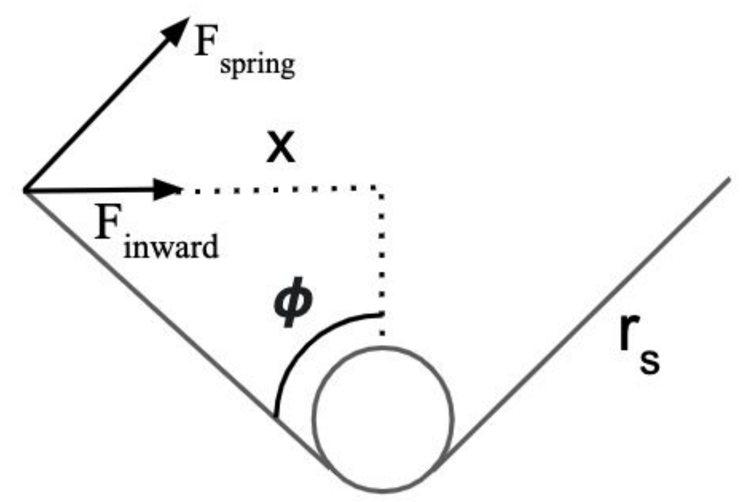


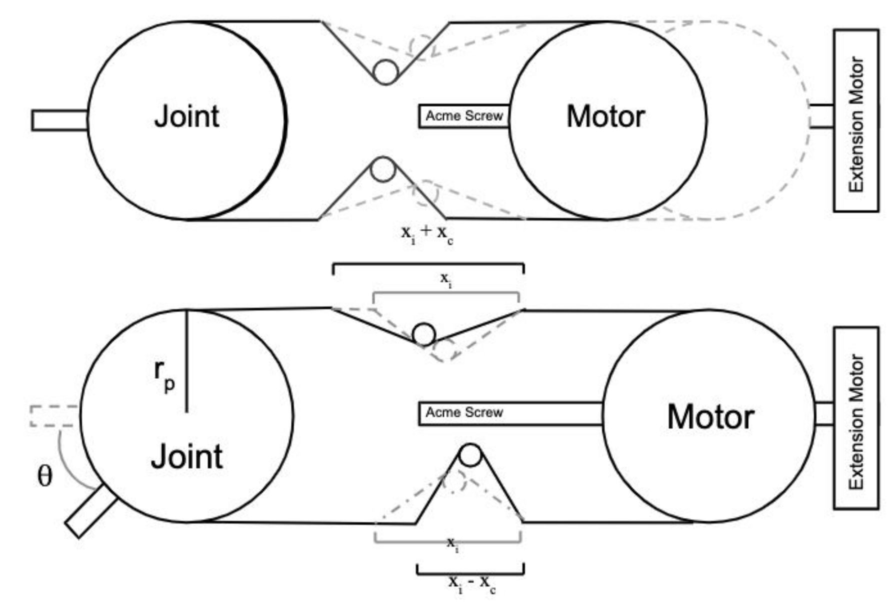
- We aim to apply this actuator to a legged robot to achieve oscillation-less landings from various drop heights. This requires complete energy absorption from the springs, and balanced torques at the resting position.

Method

Torsion Springs

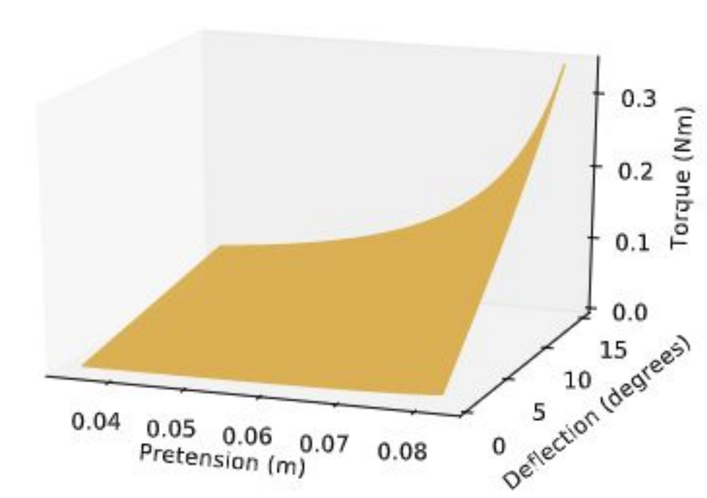
- Torsion springs have a linear angular deflection/torque relationship, but are nonlinear when extended horizontally



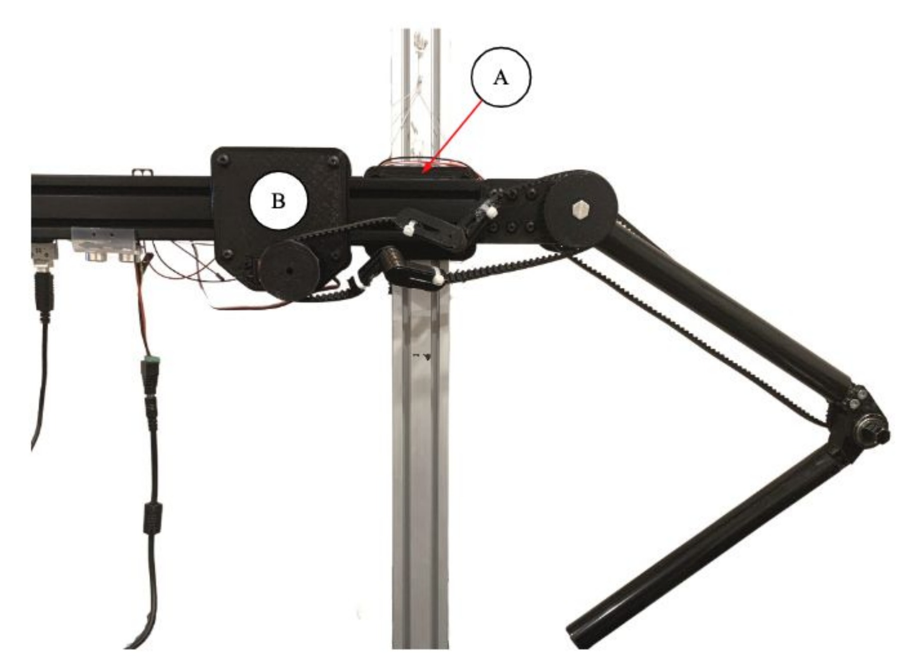


Antagonistic Setup

- By using a pair of torsion springs in a belt-drive, an extension motor can be used to vary joint stiffness.
- A large range of stiffness is achieved by control of the joint-motor distance.
- With the use of an inefficient acme screw, energy cost is significantly lowered.



Experiments

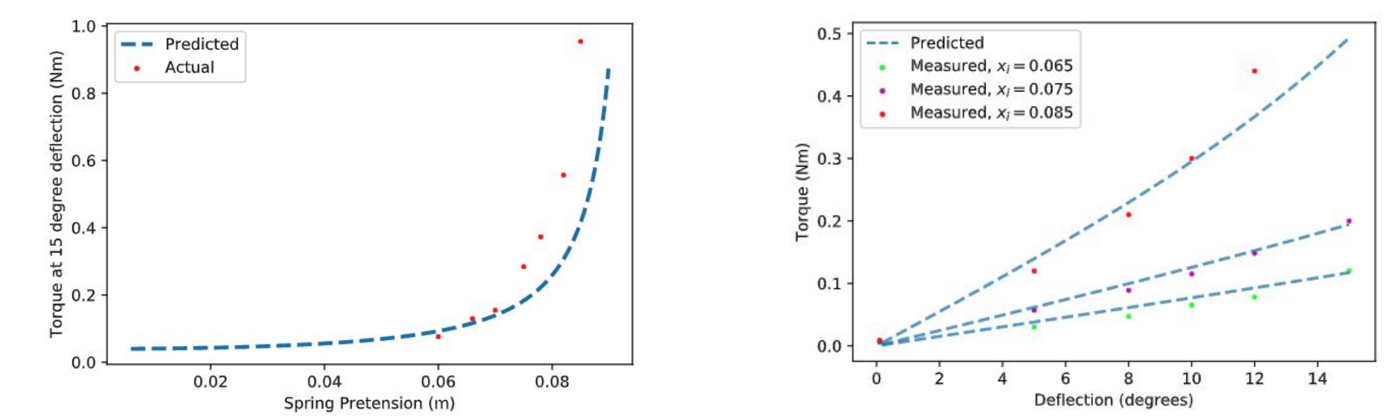


Test Platform

- We developed a single-legged system to test our design.

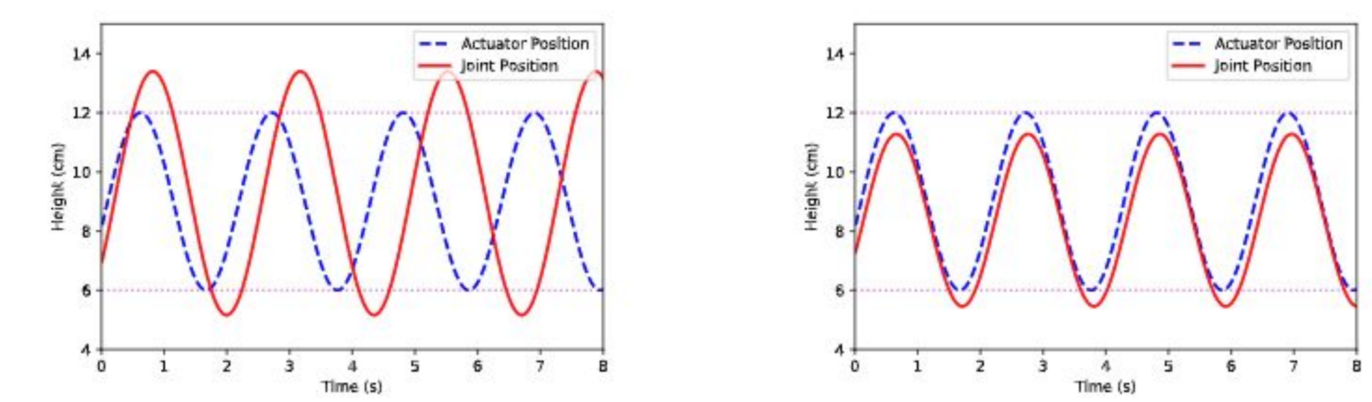
Characterization

- In comparison to theoretical models, the actuator performed similar to as expected with trivial variance.



Hopping

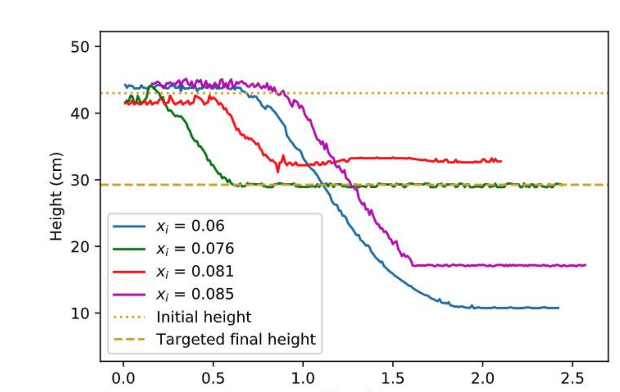
- Hopping and running share dynamic similarities, as they are cyclic motions that require the leg to apply torque.



- We compare hopping in low and high stiffness settings, and observe that the leg speed varies with stiffness.

Oscillation-less Landing

- Given a set drop height and land height, we calculate the specific joint stiffness that allows for oscillation-less landing. Experimentation shows that our predicted value varies by only 1.885%



Conclusion

- Our design is mechanically cheap and simple, and achieves a large range of stiffness for various applications.
- In the future, we hope to design a modular, revolute VSA.