CAREER: Mechanically Adaptive, Energetically Passive Robotics

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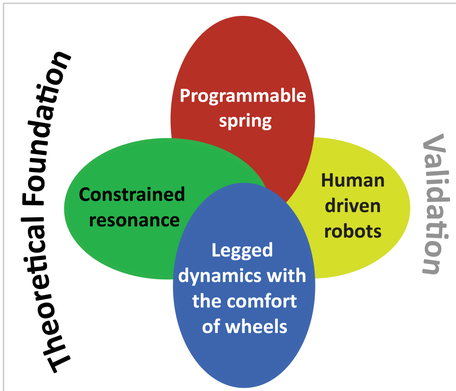
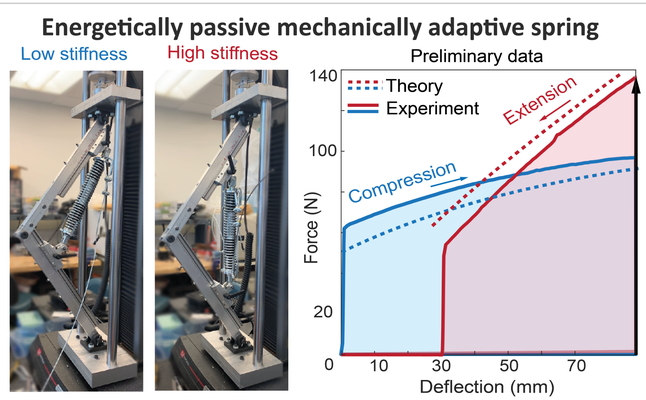
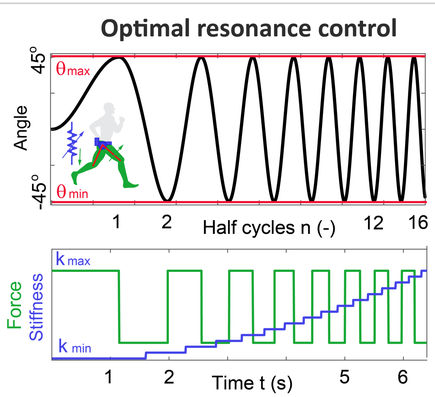
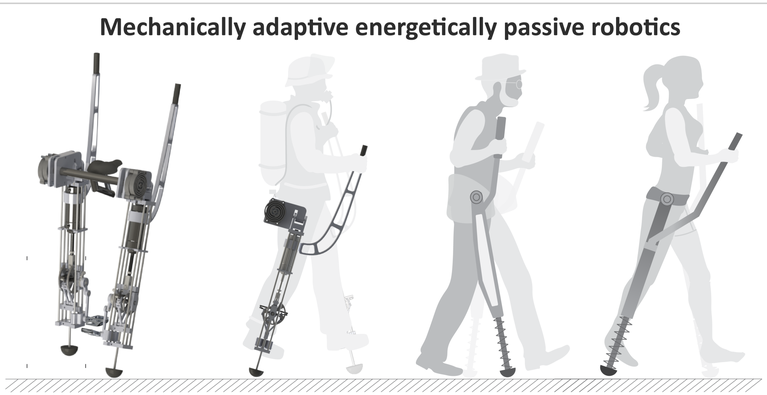
NSF | CMMI | Foundational Research in Robotics

Summary: This NSF project promotes **foundational research in the dynamics and control of mechanically adaptive but energetically passive robots**. Examples of these robots are artificial human limbs, performance-enhancing exoskeletons, legged chairs and cars, that use mechanical adaptation to reduce the need for external energy; for example, by providing optimal leverage for the human to supply more energy, or enabling a robot actuator to supply energy more efficiently.









Programmable springs are a new class of mechanical elements that:

- combine the benefit of levers and springs, and
- enable **near-zero energy cost mechanical adaptation**, (irrespective of the energy stored in the spring).

Creating such an element remains an open theoretical and practical problem.

The proposed work will advance **Scientific Knowledge** by:

- **comprehensive models** enabling the creation of programmable springs;
- a data-driven optimal control **method of** programmable springs; and
- a dynamical system **theory of programmable spring legs** that bridges the gap between legged locomotion and wheeled transportation.

Impact on Society:

We envision mechanically adaptive robot limbs

- facilitating the physical activity of the elderly;
- providing a new device for recreation and sports;
- helping rescue operations and law enforcement.

Education and Outreach:

The research is integrated with:

- engineering curriculum emphasizing controlled energy storage in mechanical systems;
- knowledge-based journalism about novel devices used for human augmentation and transportation.

Related works:

- M. Chase and D. Braun, Parallel Variable Stiffness Actuators, IEEE IROS, pp. 8225-8231, 2021; IEEE T-RO, 2022 (under review).
- T. Zhang, D. Braun, Human Driven Compliant Transmission Mechanism, IEEE ICRA, pp. 7094-7099, 2021; Theory of Fast Walking with Human-Driven Load-Carrying Robot Exoskeletons, IEEE TNSRE 2022 (under review).
- S. Kim, D. Braun, Novel Variable Stiffness Spring Mechanism: Modulating Stiffness Independent of the Energy Stored by the Spring, IEEE IROS, pp. 8232-8237, 2021; Controllable Mechanical-domain Energy Accumulators, IEEE IROS, 2022 (under review).

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