Optimal Design of Robust Compliant Actuators for Ubiquitous Co-Robots

Robert Gregg (Michigan/Lead PI), Siavash Rezazadeh (Denver Co-PI), Elliott Rouse (Michigan PI)

Key problems to address:

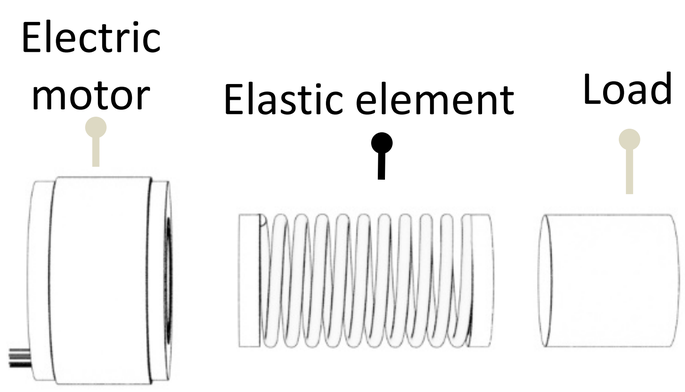
Framework for nonlinear springs acknowledging uncertainty

Achieve global solutions in polynomial-time

Solution independent of initial conditions

Avoid overdesign or underdesign resulting from safety factors

Challenge: Use series elasticity to minimize energy consumption and satisfy actuator constraints despite uncertainty



Series **E**lastic **A**ctuator (**SEA**)

Scientific Impact:

Formulate spring design of SEAs as a convex program

Framework to guarantee performance in uncertain environments

Bridge robust optimization and mechatronic design

Robust Convex Optimization Program

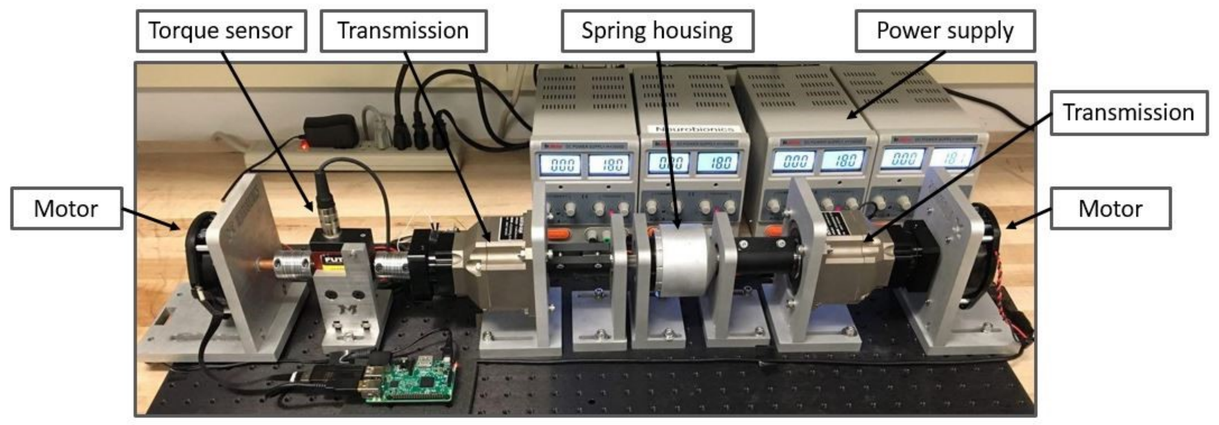
Motor energy consumption
(x: Spring compliance vector)

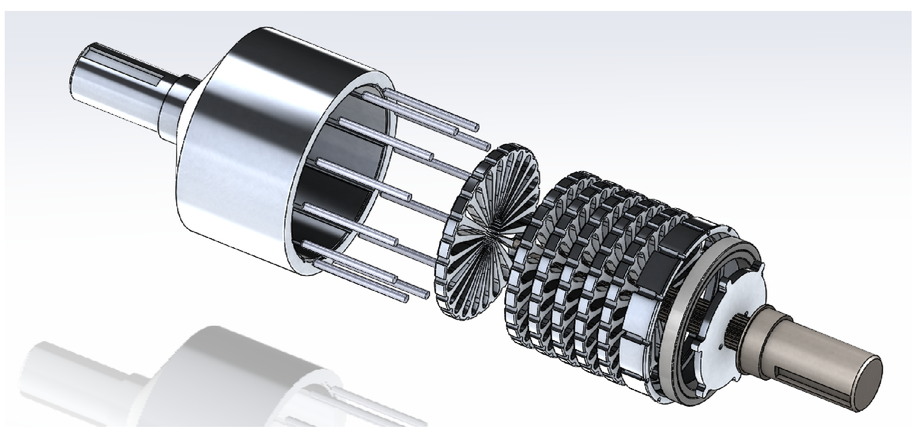
$$\textbf{minimize } \frac{1}{2}x^T Q x + q^T x + c$$
$$\textbf{subject to } Ax \leq b, \forall A, b \in \boldsymbol{\mathcal{U}}$$

Constraints
Motor torque
Motor velocity
Spring elongation

Uncertainty
Load kinematics
Load kinetics
Unmodeled dynamics
Spring manufacturing

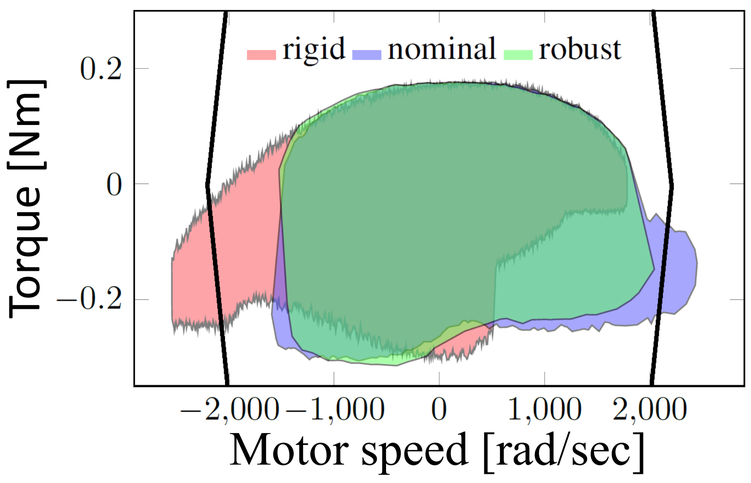
Experimental Testbed



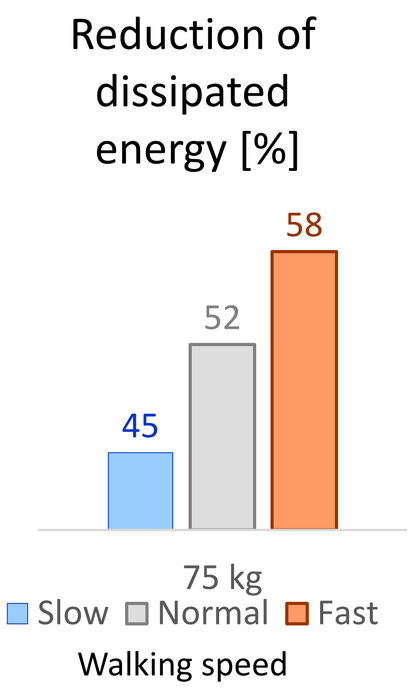


Rotational Springs can connect in parallel to modify stiffness

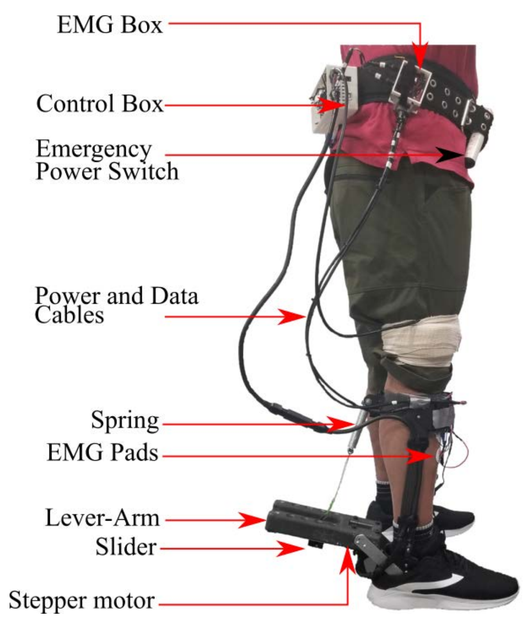
Simulation Results



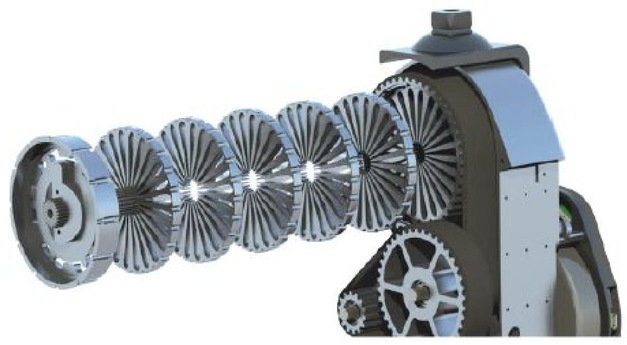
Simulation results: SEA for a powered prosthetic ankle. Not too rigid, not too soft to guarantee actuator constraints. (Nominal: 217.4 N·m/rad, Robust: 243.4 N·m/rad)



Outreach



Senior design project – UT Dallas



Open Source Leg – U. Michigan

2020 National Robotics Initiative (NRI) Principal Investigators' Meeting
FEBRUARY 27 - 28, 2020 | ARLINGTON, VIRGINIA

Award ID#:
1953908, 1830338