Anthropomorphic Robotic Ankle Prosthesis with Programmable Materials

NRI: INT: COLLAB: Anthropomorphic Robotic Ankle Prosthesis with Programmable Materials/Award #1830460 (1921046, 2025797), 2018. Poster #xx

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Challenge

To decouple the torque control of the ankle from the impedance modulation, and potentially add versatility to robotic ankle-foot prostheses

Solution

To consolidate the impedance control of the ankle robot to a mechanical module, capable of following the time-varying 2-D mechanical impedance of ankle

Scientific Impact

- To explore the adaptive dynamic behavior of the human ankle during gait in arbitrary directions
- To incorporate anthropomorphic considerations in real-time control of assistive robots

Broader Impact

- Improved well-being and activities of daily living for amputees
- Engaging k-12 to graduate students in research, education, and outreach

Thrust 1: Estimate ankle impedance during the stance phase in different gait scenarios and implement in the design and control of a 2-DOF prosthesis.
PI: Mo Rastgaar, Purdue University

2-DOF perturbation platform

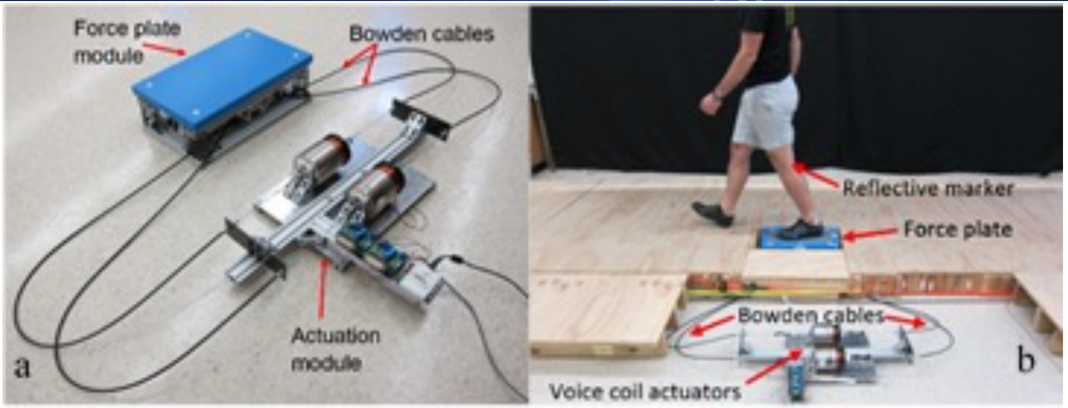
- Subject can stand, walk straight, or turn
- Actuate the platform with PRBS or step perturbations

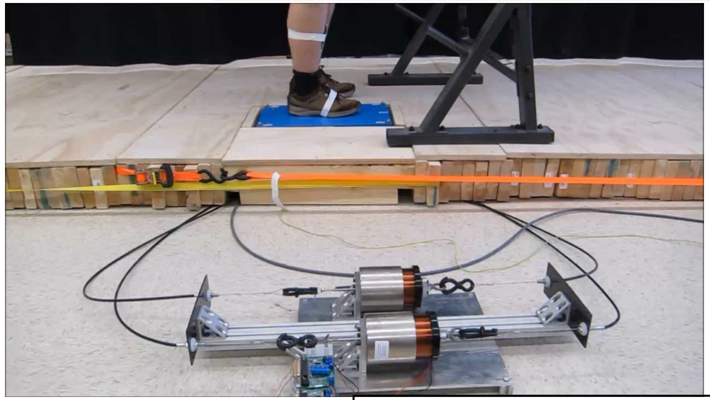
Measurements

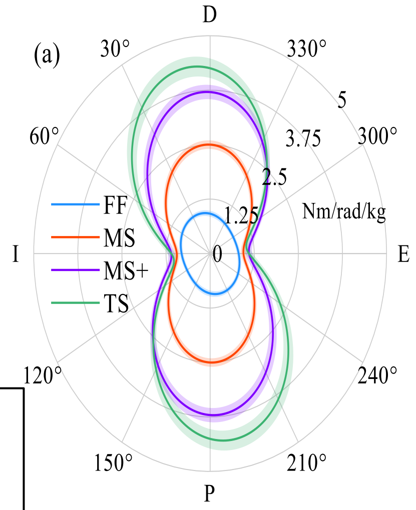
- Track pose of force plate, foot, and shank with motion capture system
- Ground reaction force and moment

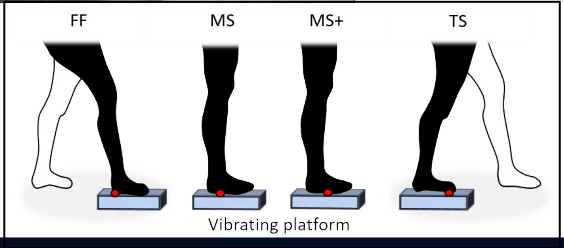
Post-Calculations

- Eliminate dynamics of the platform
- Ankle angle, θ, and external torque around the ankle, τ









Thrust 2: Equip an existing 2-D ankle-foot prosthesis with a controllable ankle impedance module built out of programmable material
Sub-contr. Conor Walsh (Harvard)

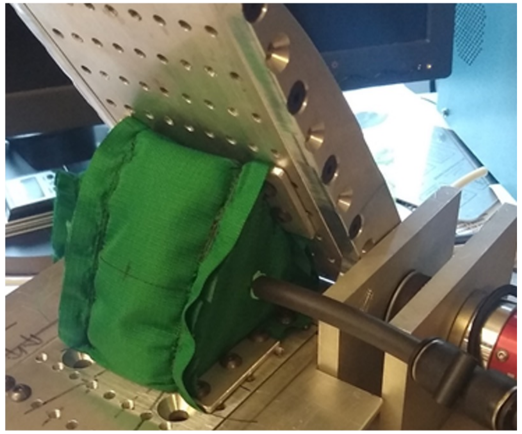
<u>Ankle Impedance Module</u>

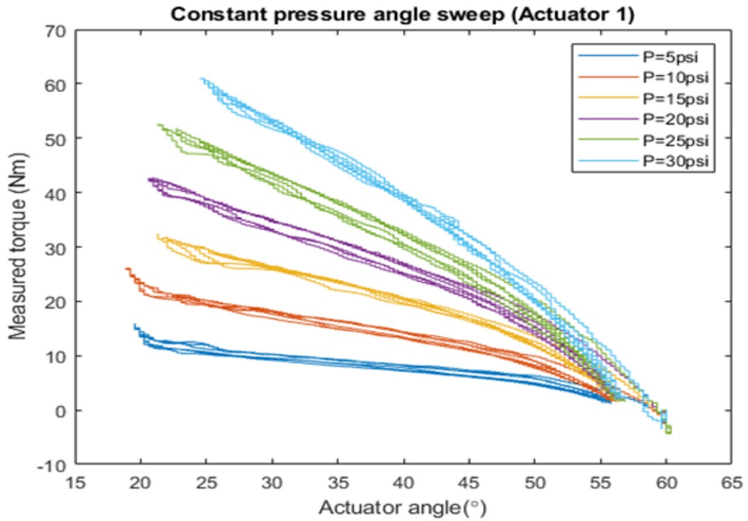
Goals:

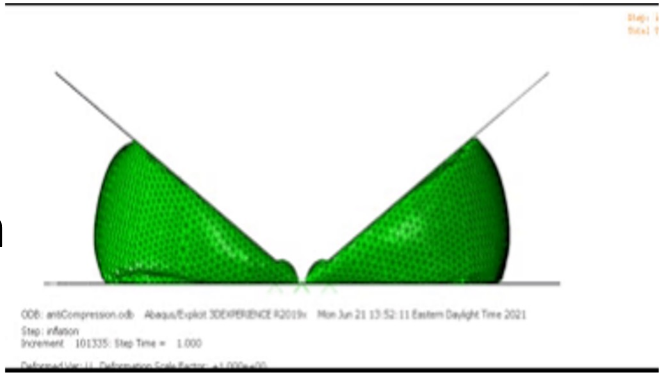
- Standalone 2 DOF impedance module that can operate in parallel to cable-based actuation of existing prosthesis
- Modulate impedance throughout the gait cycle to emulate the biological impedance of the ankle
- Leverage inherent compliance of soft actuators to reduce control complexity

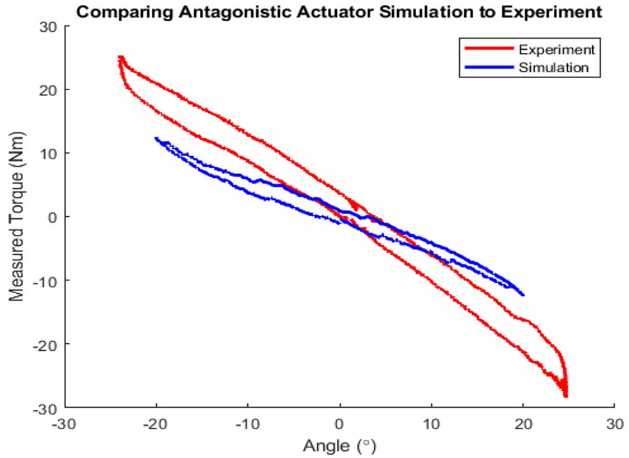
First step:

- 1DOF impedance module with unfoldin textile-based inflatable actuators to validate design approach





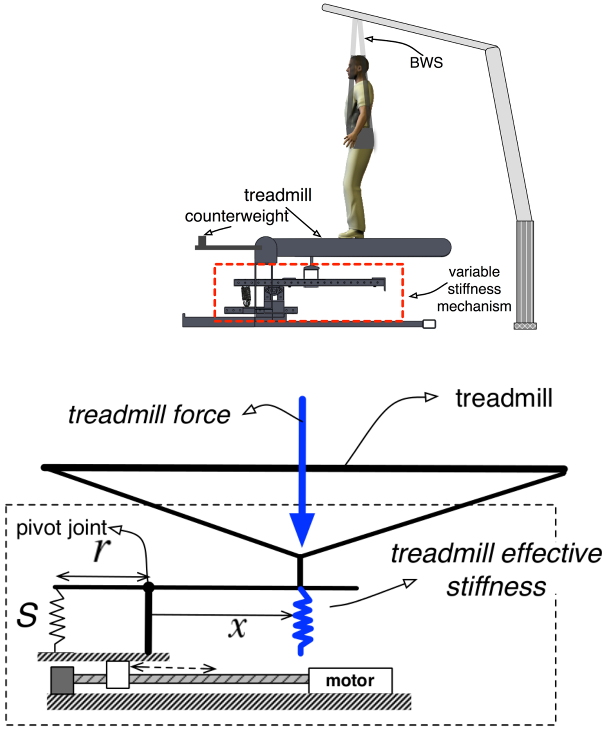




Thrust 3: Analyze the performance of the ankle-foot prosthesis with controllable impedance on scenarios that simulate real-world activities in dynamic environments
Co-PI: Panagiotis Artemiadis (University of Delaware)

Goals:

- Analyze and model muscle responses to walking surface transitions
- Investigate the effect of visual anticipation of transition to muscle and kinematics



The Variable Stiffness Treadmill (VST): a tool of investigation of gait under walking surface stiffness perturbations

Thrust 3: Analyze the performance of the ankle-foot prosthesis with controllable impedance on scenarios that simulate real-world activities in dynamic environments
Co-PI: Panagiotis Artemiadis (University of Delaware)

Main results:

- Increased TA activity for VO and VP conditions from 63-75%
- Increased TA activity is also present during the encounter of the visual sand patch from 105-125% for VO and VP conditions when the subject begins foot contact in the VR environment
- Delayed GA muscle activation for the VO condition compared to normal walking