NRI: INT: COLLAB: Muscle Ultrasound Sensing for Intuitive Control of Robotic Leg Prostheses

Nicholas Fey (PI), The University of Texas at Austin and Tommaso Lenzi (PI), The University of Utah

Problem Statement

Robotic prostheses can mimic virtually any motor behavior exhibited by the healthy limb. However, achieving this goal depends on the ability of the control system to coordinate with the user's neuromuscular system.

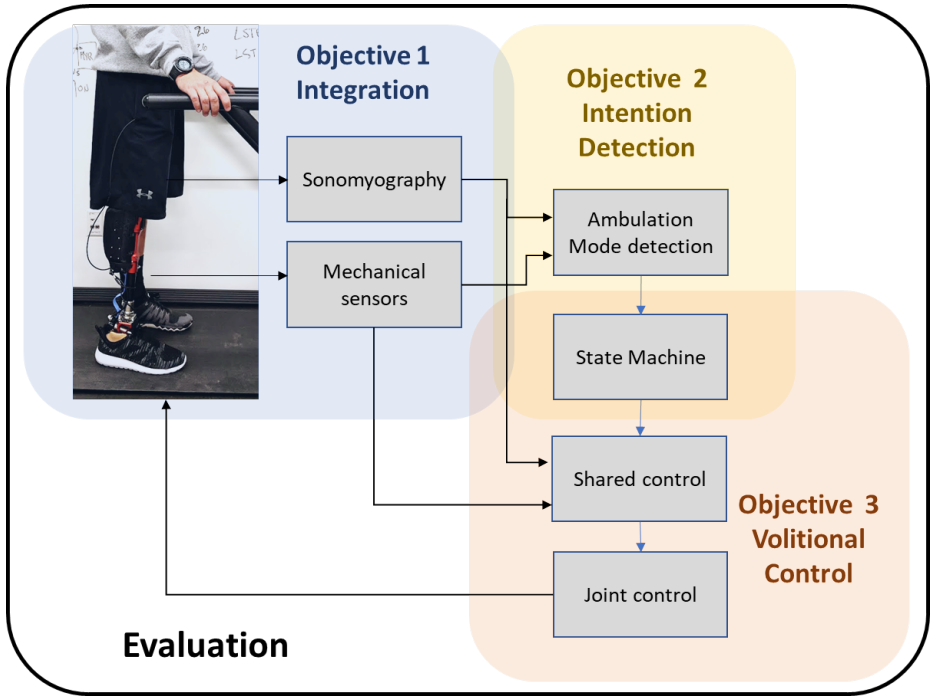
Central Hypothesis

By integrating **sonomyography** with **shared control**, robotic leg prostheses can achieve *volitional* behavior thus leading to unprecedented ubiquitous ambulation performance in complex and uncertain real-world environments.

Solution Statement

Integrate **sonomyography** and **shared robot control**.

- **Sonomyography** can provide rich information on the user's movement intention through depth-resolved imaging.
- **Shared control** can integrate the user's volition while guaranteeing robustness and intuitiveness.



Award ID # 2054343 and 1925371

SHARED CONTROL

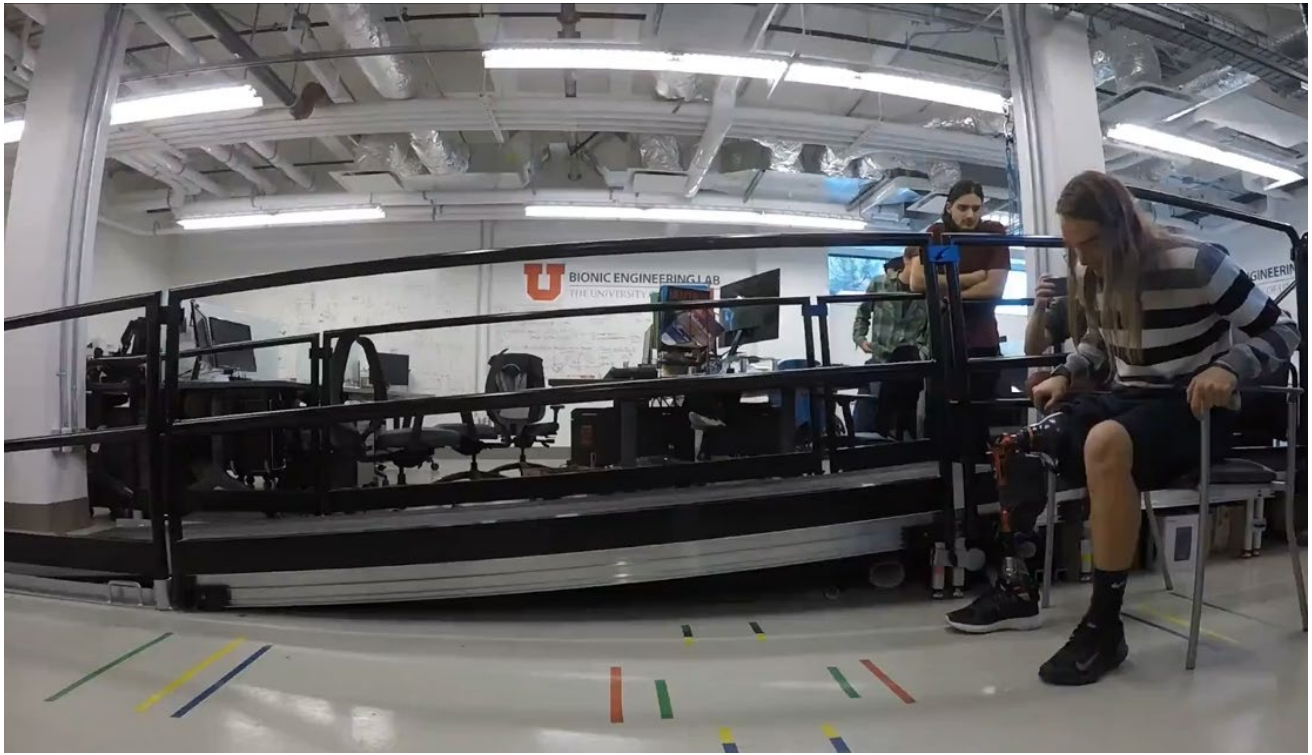
INDIRECT VOLITIONAL WALKING CONTROL

J. Mendez, S. Hood, A. Gunnel, and T. Lenzi "*Powered knee and ankle prosthesis with indirect volitional swing control enables level-ground walking and crossing over obstacles*" **Science Robotics** (2020)

INDIRECT VOLITIONAL STAIRS CONTROL

S. Hood. L. Gabert, and T. Lenzi "*Powered Knee and Ankle Prosthesis with Adaptive Control Enables Climbing Stairs with Different Stair Heights, Cadences, and Gait Patterns*" **IEEE Transactions on Robotics** (2022)

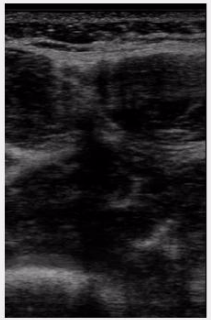
DIRECT VOLITIONAL CONTROL

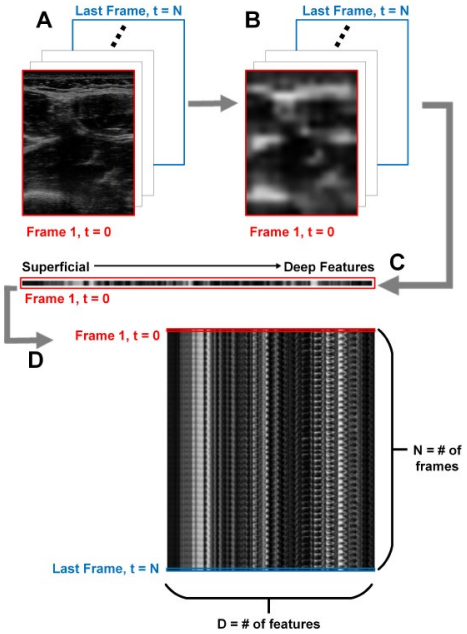


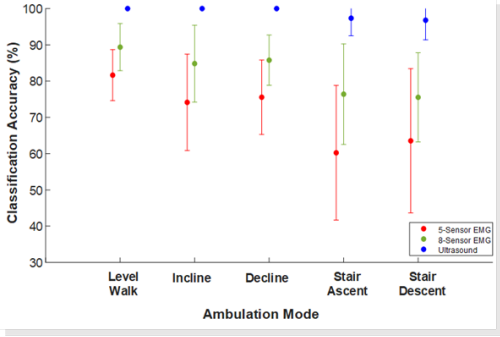
G. R. Hunt, S. Hood and T. Lenzi, "Stand-Up, Squat, Lunge, and Walk With a Robotic Knee and Ankle Prosthesis Under Shared Neural Control," **IEEE Open Journal of Engineering in Medicine and Biology** (2021)

SONOMYOGRAPHIC CONTROL

CONTINUOUS CLASSIFICATION OF AMBULATION





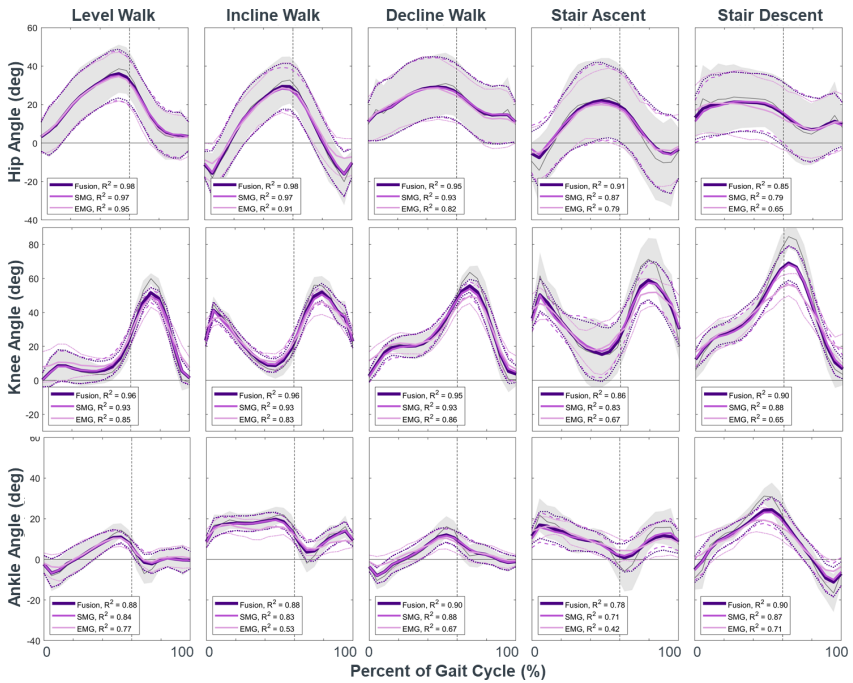


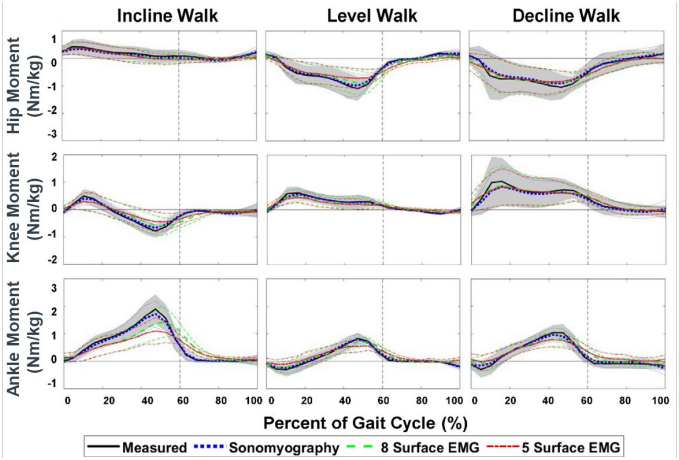
Accuracy		Predicted Class				
		W	I	D	SA	SD
True Class	W	100.0% (0.0)	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)
	I	0.0% (0.0)	100.0% (0.0)	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)
	D	0.0% (0.0)	0.0% (0%)	100.0% (0.0)	0.0% (0%)	0.0% (0%)
	SA	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)	97.6% (3.6)	2.4% (3.6)
	SD	0.0% (0.0)	0.0% (0.0)	0.0% (0.0)	2.4% (2.3)	97.6% (2.3)

W: walk; I: incline; D: decline; SA: stair ascent; SD: stair descent.

KG Rabe et al. *"Ultrasound Sensing Can Improve Continuous Classification of Discrete Ambulation Modes Compared to Surface Electromyography"* **IEEE Transactions on Biomedical Engineering** (2020)

CONTINUOUS PREDICTION OF JOINT MECHANICS

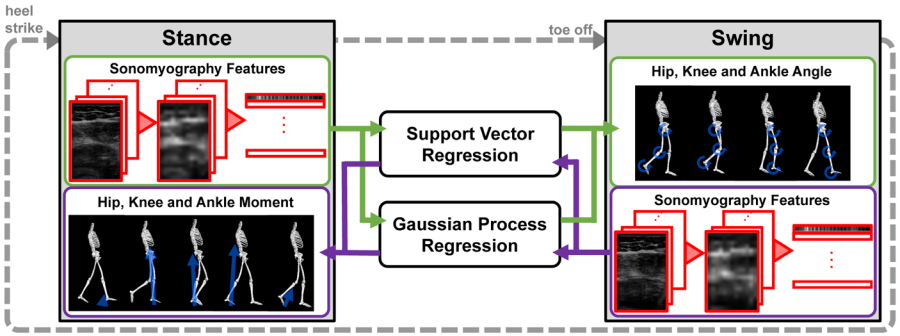


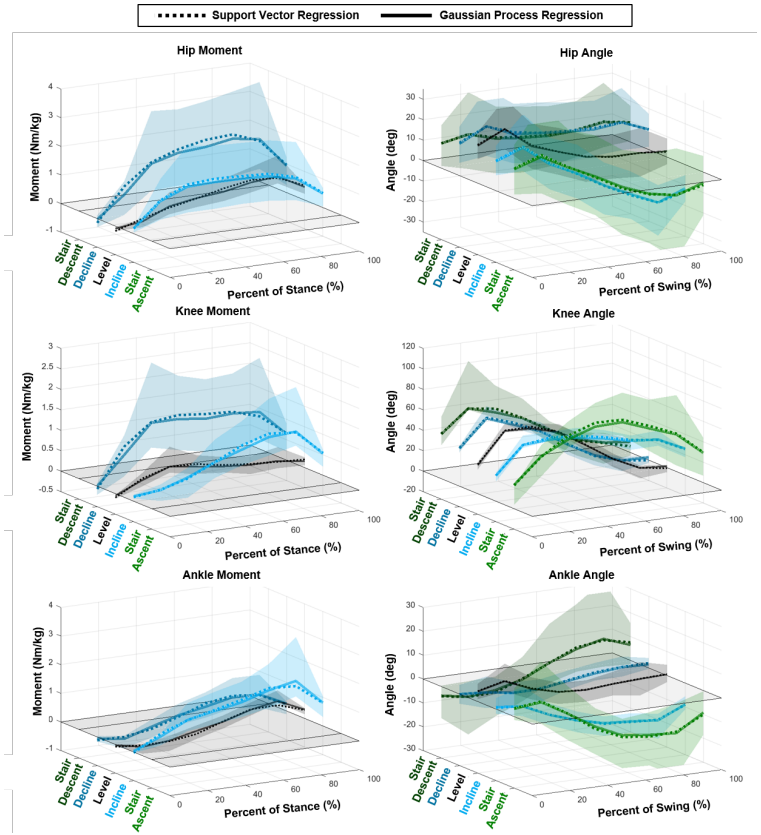


Rabe, KG, Lenzi, T and Fey, NP. *"Performance of sonomyographic and electromyographic sensing for continuous estimation of joint torque during ambulation on multiple terrains"* **IEEE Transactions on Neural Systems and Rehabilitation Engineering** (2021)

Rabe, KG and Fey, NP. *"Evaluating electromyography and sonomyography sensor fusion to estimate lower-limb kinematics using Gaussian process regression"* **Frontiers in Robotics and AI** – Special Issue on User-Adaptive Wearable Robots (2022).

FUTURE PREDICTION OF POSITION AND TORQUE





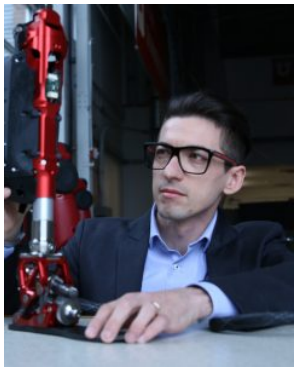
Rabe, KG and Fey, NP. *"Forward models that integrate high-dimensional and localized sensing of peripheral muscle behavior enable task-independent future prediction of lower-extremity torque and position trajectories"* **IEEE International Conference on Robotics and Automation** (ICRA), (2022)

The University of Texas at Austin
Cockrell School of Engineering

BIONIC ENGINEERING LAB
THE UNIVERSITY OF UTAH

FUTURE

- Sonomyography and transfemoral amputation
- Online volitional control using sonomyography



Thank you!