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

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https://belab.mech.utah.edu/sonomyography/

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. Neural signals generated by the user's neuromuscular system can provide information on the user's movement intention as necessary for a *volitional* control strategy. Electromyography has been typically used a proxy for neural commands. However, its performance is negatively affected by the poor signal to noise ratio, the lack of specificity to individual deep-seated muscles, and poor reliability over an extended period.

Solution Statement

Integrate muscle ultrasound, namely **sonomyography**, and **shared robot control**.

- **Sonomyography** can provide rich information on the user's movement intention through depth-resolved imaging of specific muscles and functional muscle compartments.
- **Shared control** has the potential to integrate the user's volition into the robotic leg control system, while guarantying the levels of robustness and intuitiveness necessary for ambulation.

Central Hypothesis

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

Scientific Impact

This proposal will advance knowledge of how to integrate the user's intention with the robot control to develop *volitional* control systems. Beyond prostheses, the proposed paradigm can be used to improve the performance of other wearable robots such as powered exoskeletons to assist individuals with neurological impairments.

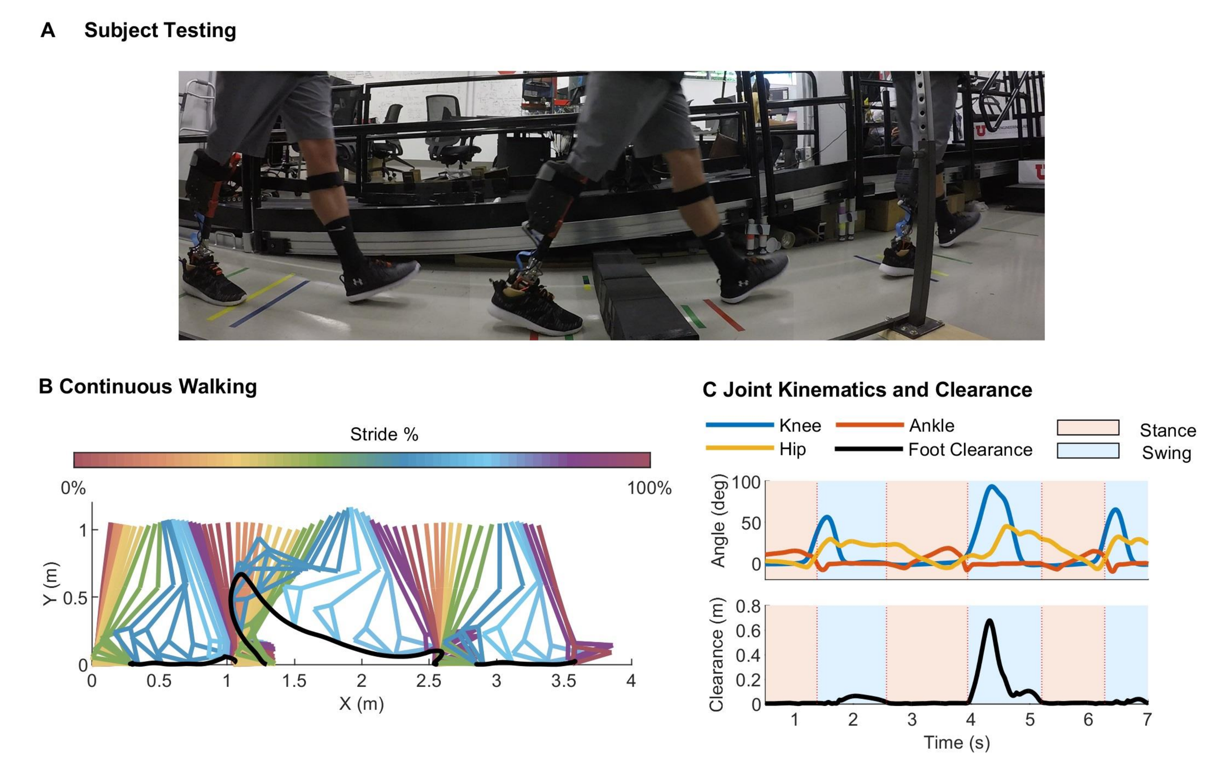
Broader Impact

Societal Impact: enabling a new generation of robotic leg prostheses that provide greater mobility and independence to individuals with lower-limb amputation.

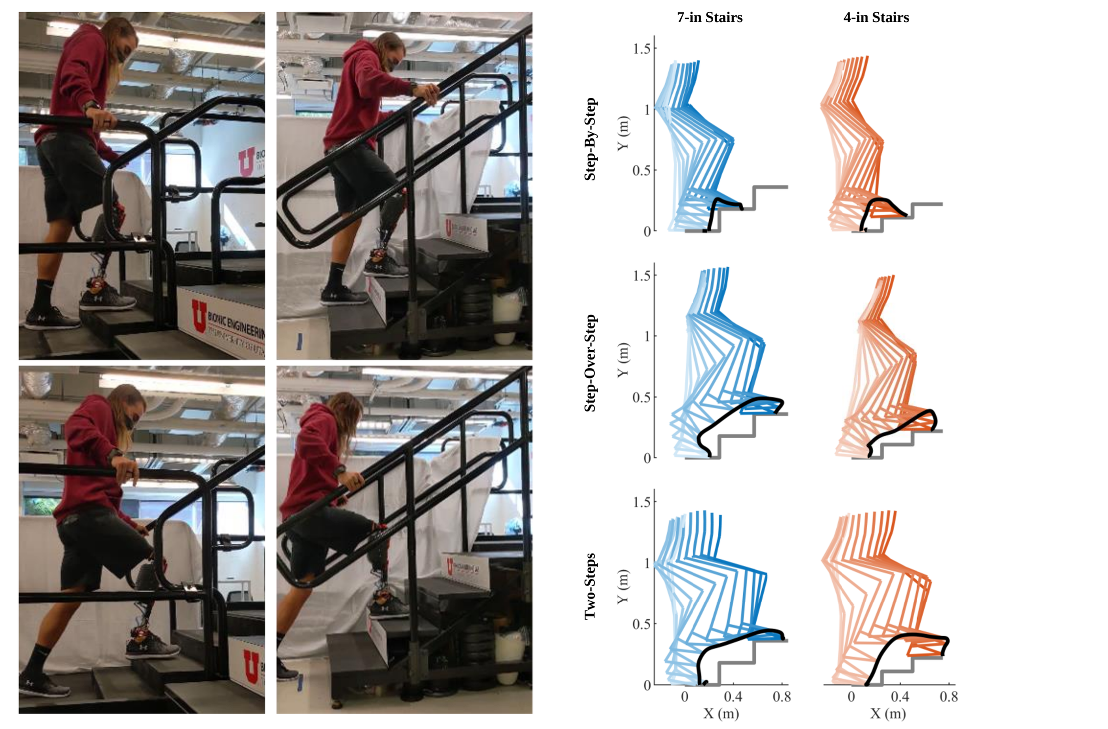
Educational Impact: Advance knowledge and understanding of robotics and design concepts through STEM camps, design projects for college seniors, including a joint internship program between the University of Utah and Ottobock Salt Lake City.

Results

We have developed a volitional swing controller that continuously adapt the movements of the prosthesis to the movement of the user. This controller enabled individuals to walk while seamlessly crossing over obstacles and climb stairs with different stair heights, cadences, and gait patterns.

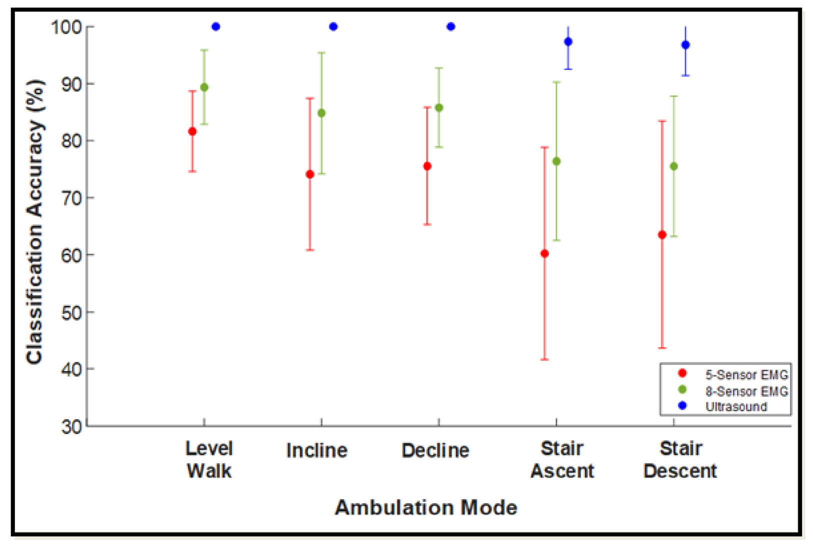


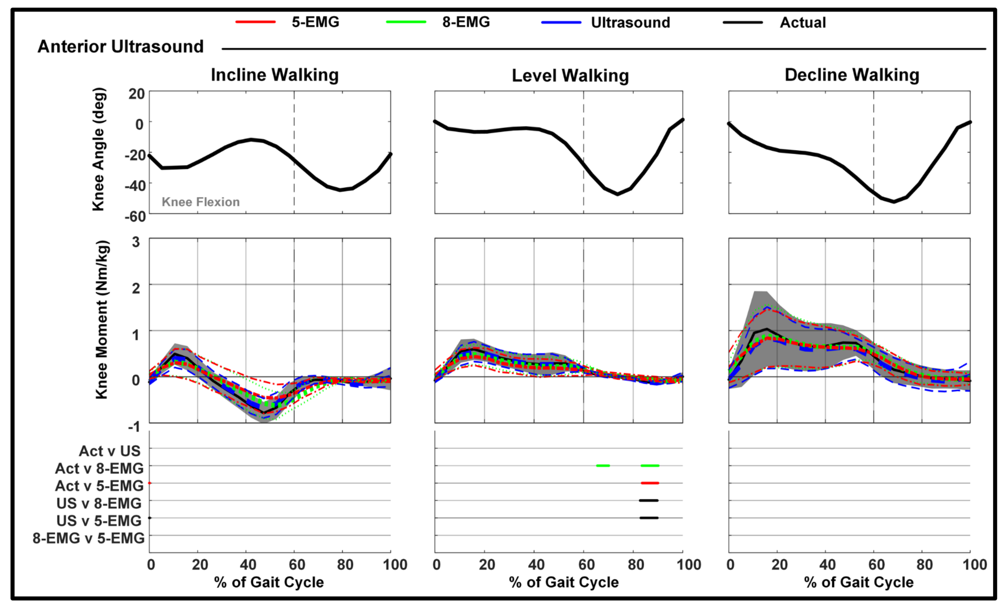
J. Mendez, S. Hood, A. Gunnel, and T. Lenzi *"Powered knee and ankle prosthesis with indirect volitional swing control enables level-ground walking and crossing over obstacles"* Science Robotics 22 Jul 2020:Vol. 5, Issue 44



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 *(in review)*

We have developed algorithms that can anticipate movement intention from sonomyography of anterior or posterior thigh musculature. These algorithms can predict discrete modes of ambulation such as movement terrain, as well as joint torque and joint velocity profiles that occur during widely-varying modes of ambulation. We show sonomyography can outperform electromyography.





K.G. Rabe, M.H. Jahanandish, J.R. Boehm, A.M. Fey, K. Hoyt, and N.P. Fey *"Ultrasound Sensing Can Improve Continuous Classification of Discrete Ambulation Modes Compared to Surface Electromyography"* IEEE Transactions on Biomedical Engineering (2020)
M.H. Jahanandish, K.G. Rabe, K. Hoyt, and N.P. Fey *"Ultrasound Features of Skeletal Muscle Can Predict Kinematics of Upcoming Lower-Limb Motion"* Annals of Biomedical Engineering 49, no. 2 (2021): 822-833
K.G. Rabe, M.H. Jahanandish, K. Hoyt, and N.P. Fey *"Use of Sonomyography for Continuous Estimation of Hip, Knee and Ankle Moments during Multiple Ambulation Tasks"* 8th IEEE RAS/EMBS International Conference for BioRobotics and Biomechatronics (BioRob) (Nov. 2020)
K.G. Rabe, M.H. Jahanandish, K. Hoyt, and N.P. Fey (2020). *"Use of Sonomyographic Sensing to Estimate Knee Angular Velocity during Varying Modes of Ambulation"* 42nd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (July 2020)
K.G. Rabe, T. Lenzi, and N.P. Fey *"Comparison of Sonomyography and Electromyography for Continuous Estimation of Joint Torque During Multiple Forms of Ambulation"* IEEE Transactions on Neural Systems and Rehabilitation (*in review*)