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

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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. Signals from the user's neuromuscular system can provide information on the user's movement intention as necessary for a volitional control strategy.

- **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.

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

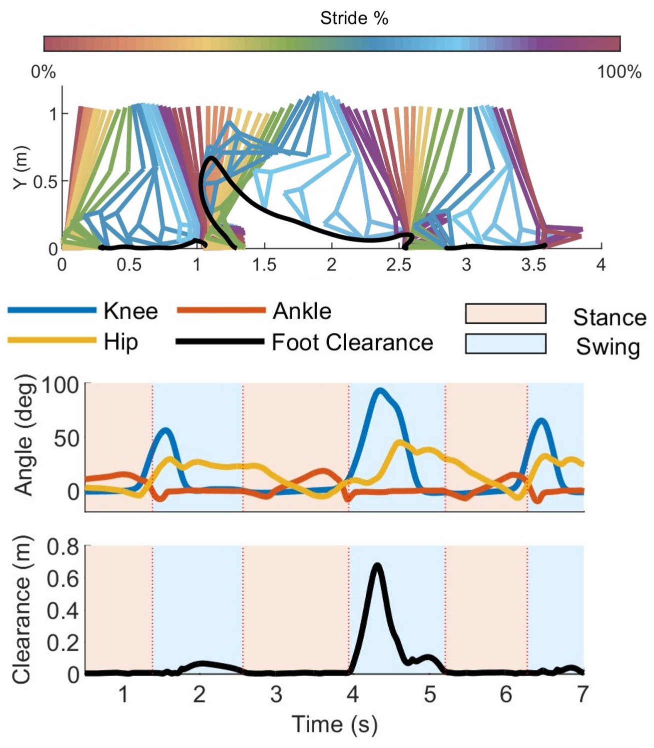
This proposal will advance knowledge of how to integrate the user's intention with the robot control to develop *volitional* control systems. Beyond prostheses, the proposed paradigm can be used to improve the performance of other wearable robots such as powered exoskeletons to assist individuals with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

Broader Impact

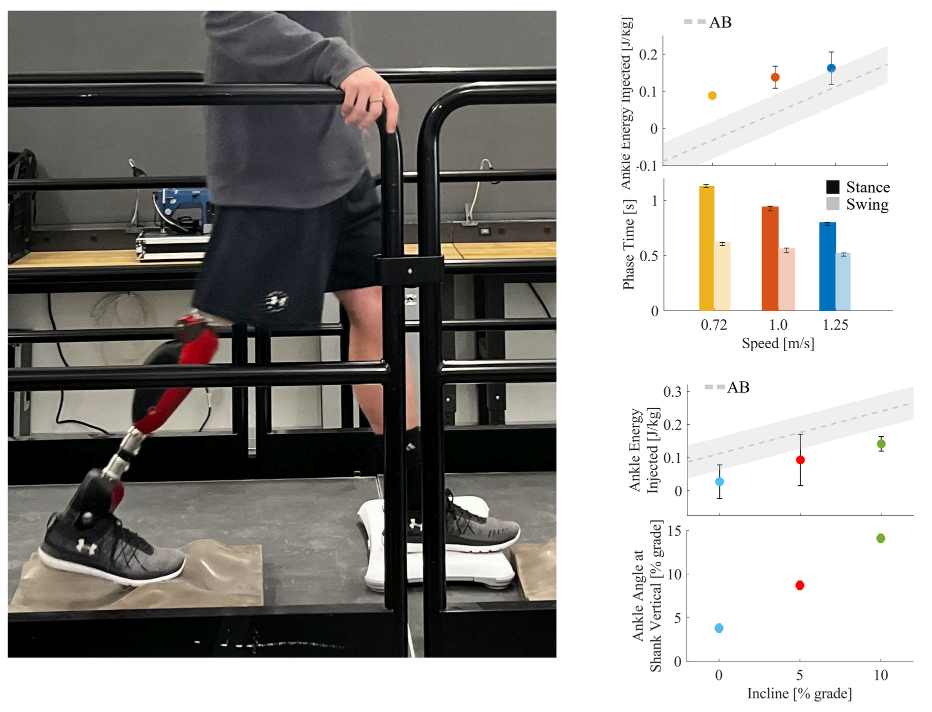
Societal Impact: enabling a new generation of robotic leg prostheses that provide greater mobility and independence to individuals with lower-limb amputation.

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.

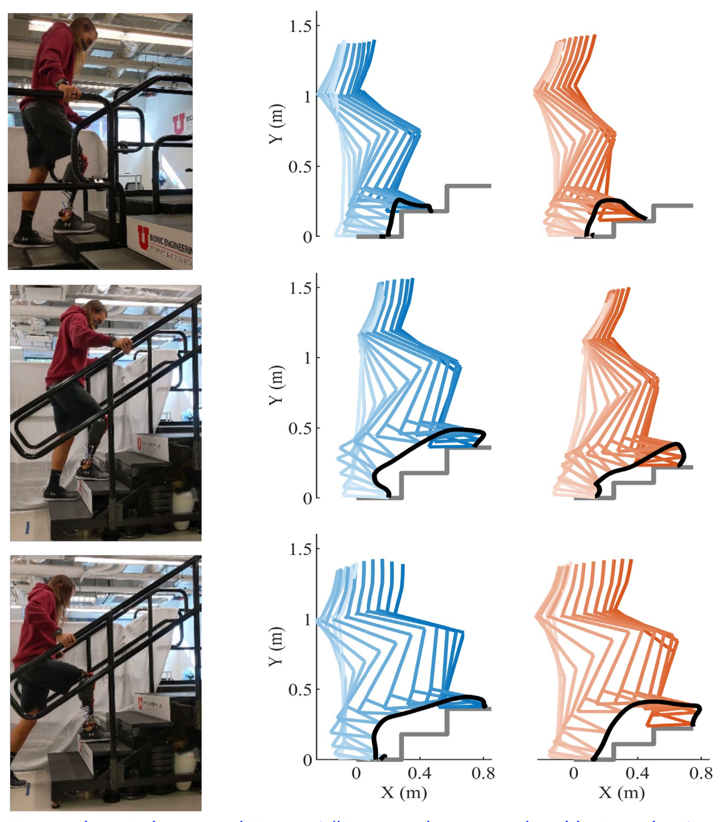
Indirect Volitional Control



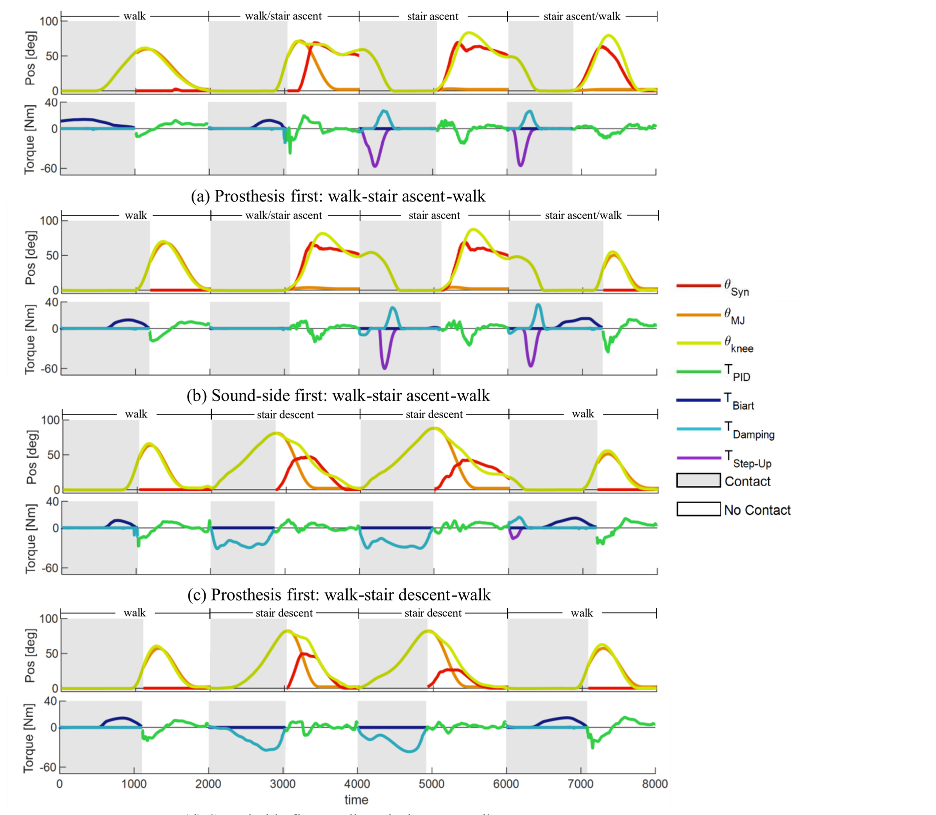
J. Mendez, S. Hood, A. Gunnel, and T. Lenzi *"Powered knee and ankle prosthesis with indirect volitional swing control enables level-ground walking and crossing over obstacles"* Science Robotics 22 Jul 2020:Vol. 5, Issue 44



L.M Sullivan, S. Creveling, M. Cowan, L. Gabert, T. Lenzi, "A Unified Controller for Natural Ambulation on Stairs and Level Ground with a Powered Robotic Knee Prosthesis," in 2023 IEEE International Workshop on Intelligent Robots and Systems (IROS), Oct. 2023. (Submitted)

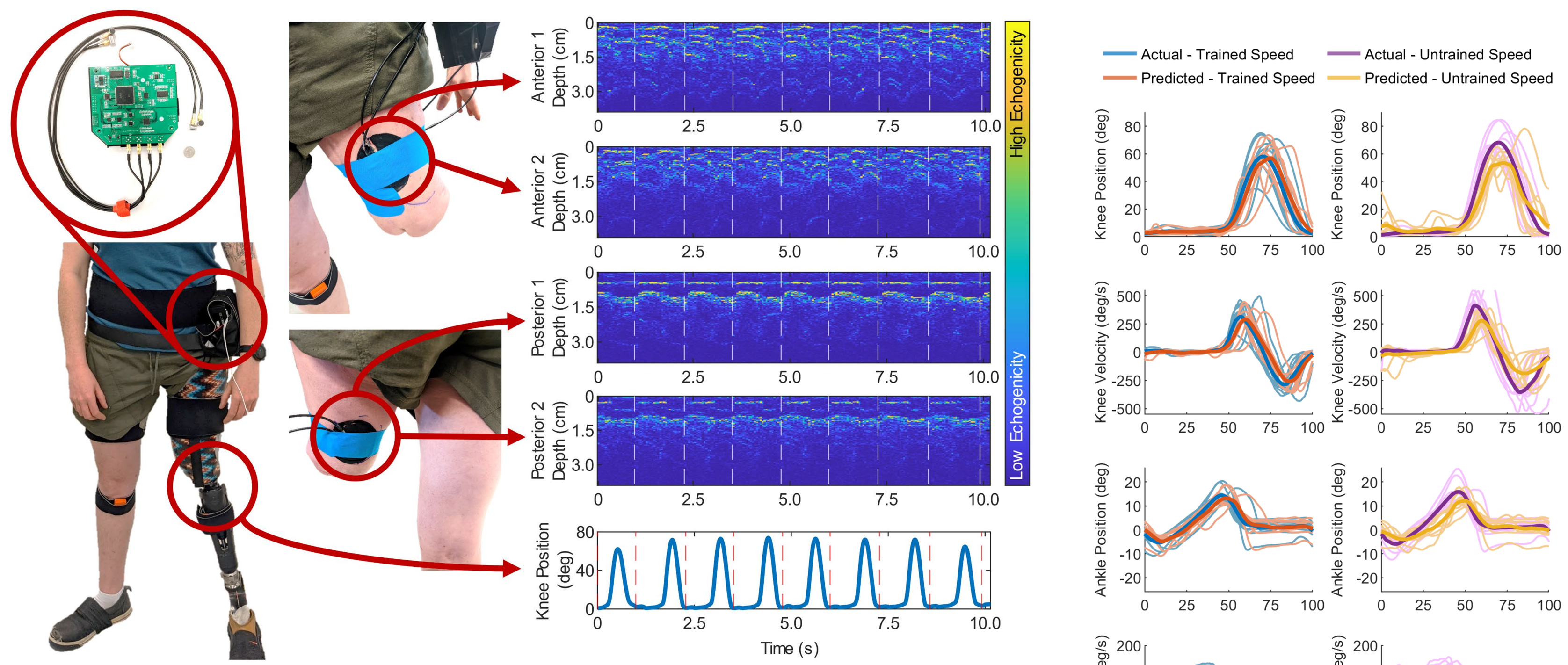


S. Hood. L. Gabert, and T. Lenzi *"Powered Knee and Ankle Prosthesis with Adaptive Control Enables Climbing Stairs with Different Stair Heights, Cadences, and Gait Patterns"* IEEE Transactions on Robotics doi: 10.1109/TRO.2022.3152134.

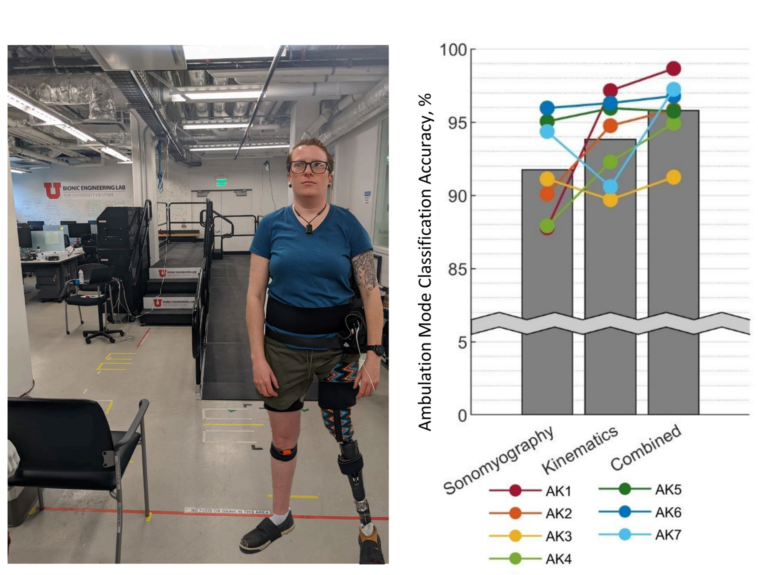


M. Cowan, S. Creveling, L. M. Sullivan, L. Gabert, T. Lenzi, "A Unified Controller for Natural Ambulation on Stairs and Level Ground with a Powered Robotic Knee Prosthesis," in 2023 IEEE International Workshop on Intelligent Robots and Systems (IROS), Oct. 2023. (Submitted)

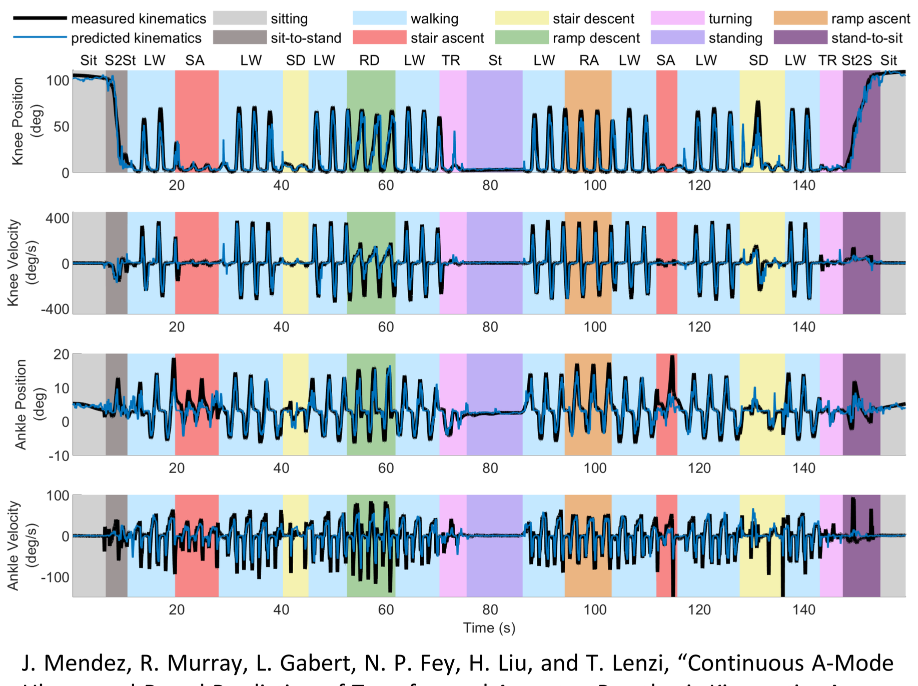
Sonomyography



J. Mendez, R. Murray, L. Gabert, N. P. Fey, H. Liu, and T. Lenzi, "A-Mode Ultrasound-Based Prediction of Transfemoral Amputee Prosthesis Walking Kinematics Via an Artificial Neural Network," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 31, pp. 1511–1520, Mar. 2023, doi: 10.1109/TNSRE.2023.3248647.

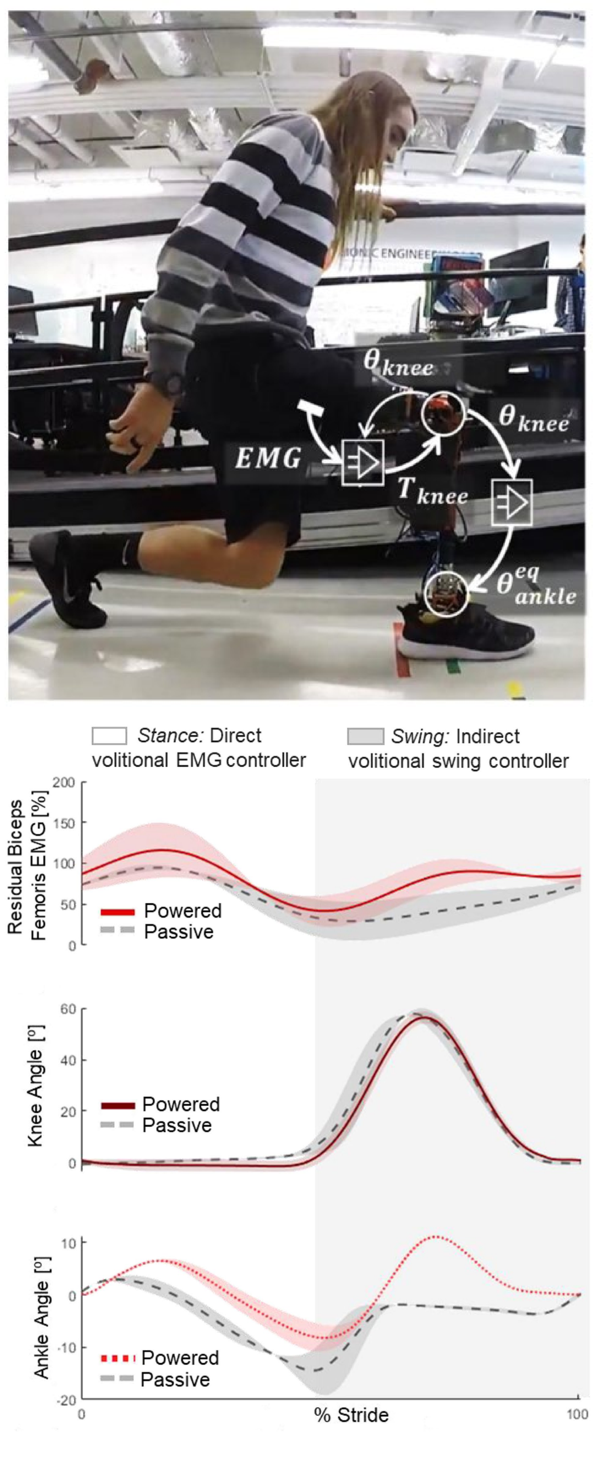


R. Murray, J. Mendez, L. Gabert, N. P. Fey, H. Liu, and T. Lenzi, "Ambulation Mode Classification of Individuals with Transfemoral Amputation through A-Mode Sonomyography and Convolutional Neural Networks," Sensors, vol. 22, no. 23, p. 9350, Dec. 2022, doi: 10.3390/s22239350.



J. Mendez, R. Murray, L. Gabert, N. P. Fey, H. Liu, and T. Lenzi, "Continuous A-Mode Ultrasound-Based Prediction of Transfemoral Amputee Prosthesis Kinematics Across Different Ambulation Tasks," IEEE Trans. Biomed. Eng. (Submitted)

Shared Neural Control



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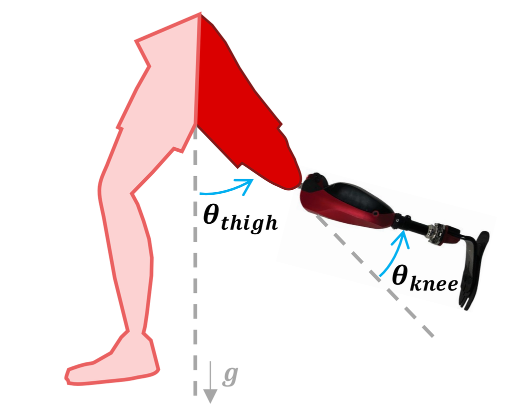

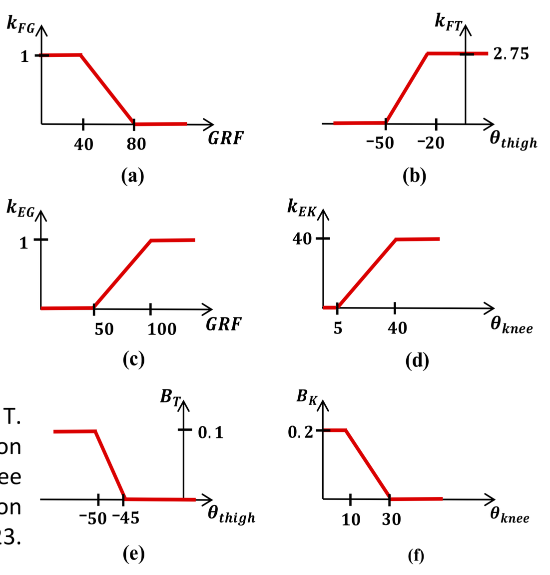

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