Dexterous Prosthesis Manipulation through Context-Driven Amputee–Prosthesis Co-Adaptation

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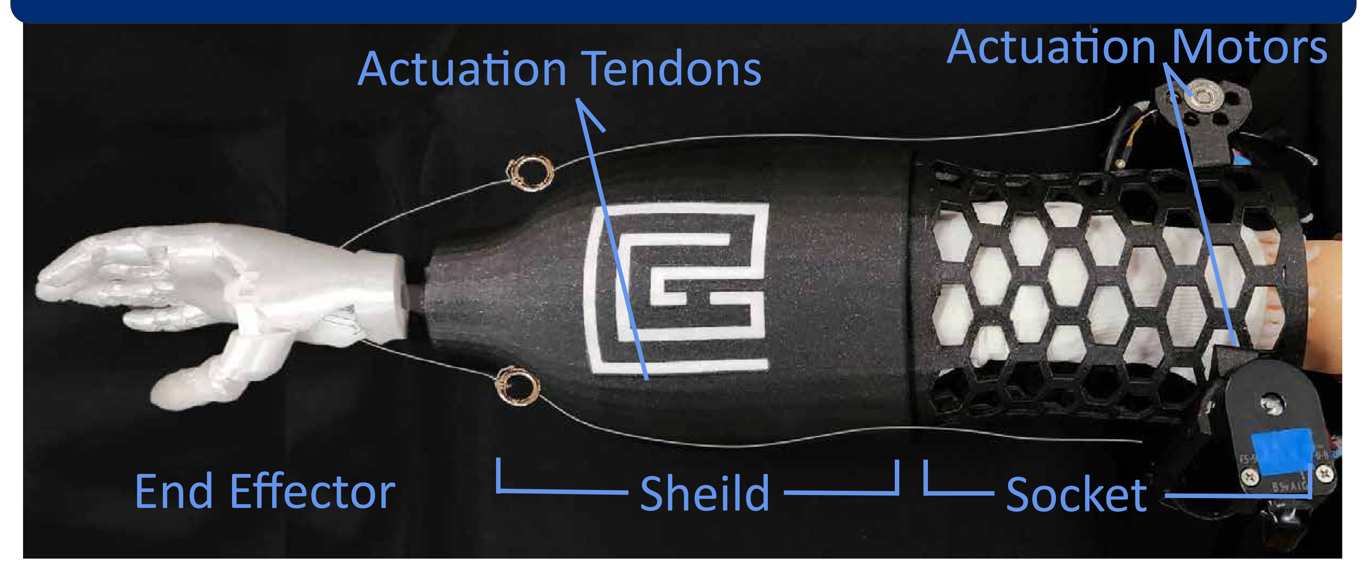
Motivation

Upper-limb prostheses exhibit high abandonment rates due to significant cognitive and physical demands arising from a mismatch with natural limb biomechanics.

Hypothesis

This work explores how biologically inspired tendon mechanics, musculoskeletal-informed control, and state-based haptic feedback can enhance performance and reduce workload.

Tendon Actuated Modular Prosthesis

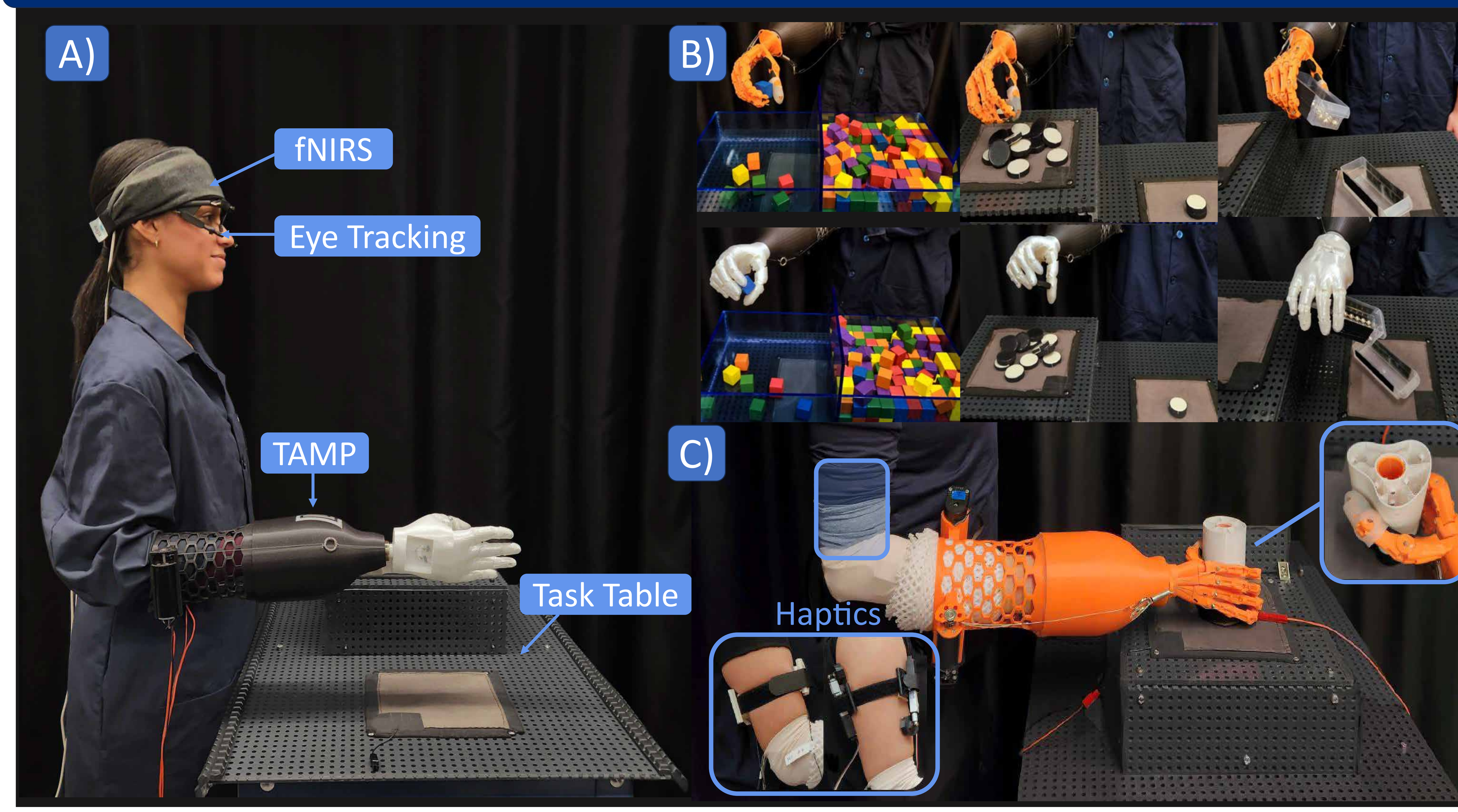


We developed a tendon-driven prosthetic platform that enables agonist–antagonist actuation and configurable control of both aperture and limb impedance.

HAMR Process

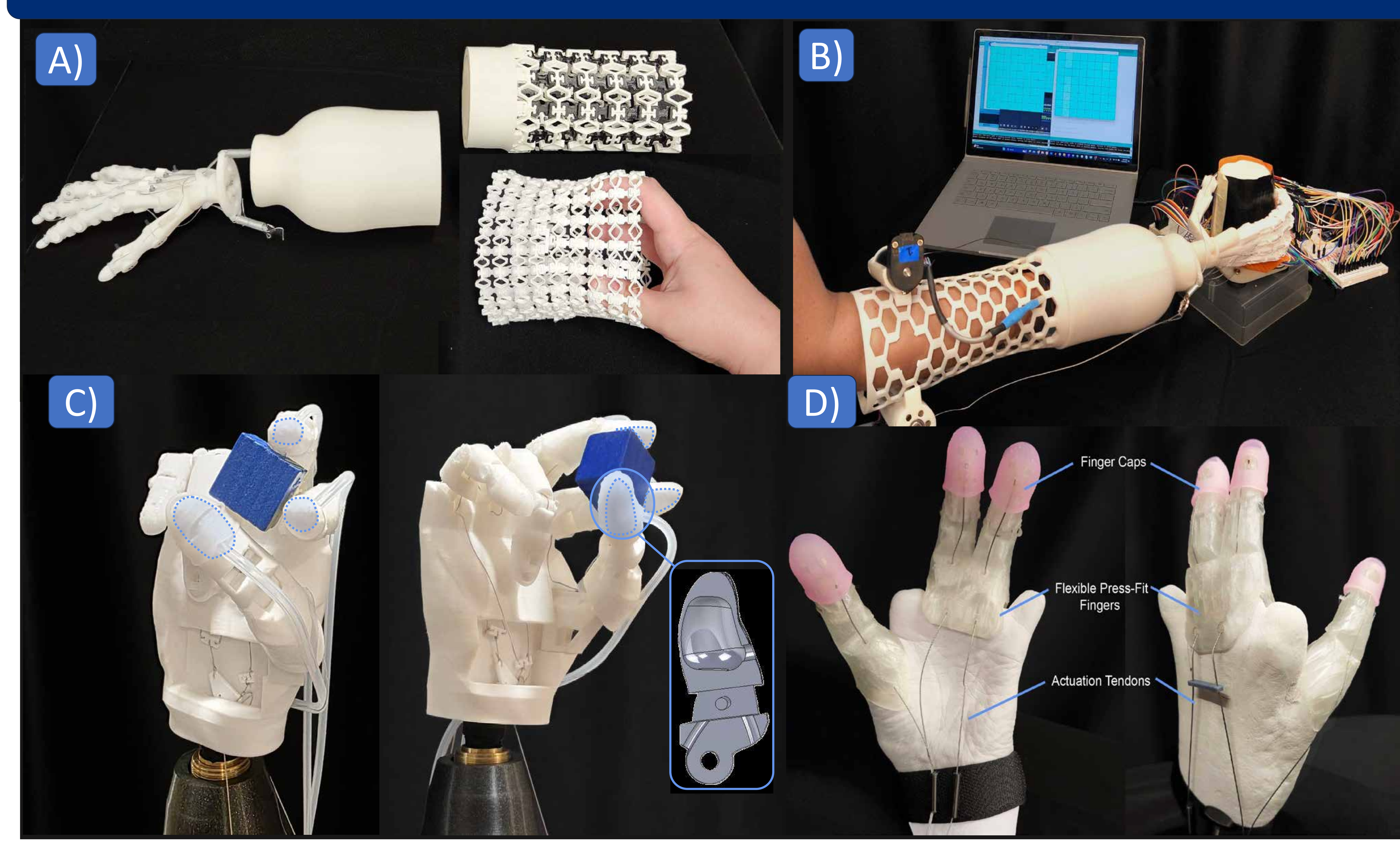
Human-Inspired Actuator Modeling and Reconstruction (HAMR) workflow for generating anatomically informed prosthetic end effectors. Using the HAMR process, we derived customized morphology and tendon routing from human anatomy to create the Tendon-Actuated Prosthetic Hand (TAPH), enabling adaptive force distribution.

Experimentation



Multimodal experimental setup showing: (A) cognitive load measurement (fNIRS, eye tracking), (B) standardized manipulation tasks (box and blocks, checker transfer and stack, and weighted carton transfer and pour), and (C) state-based haptic feedback while using TAMP.

REU Contributions

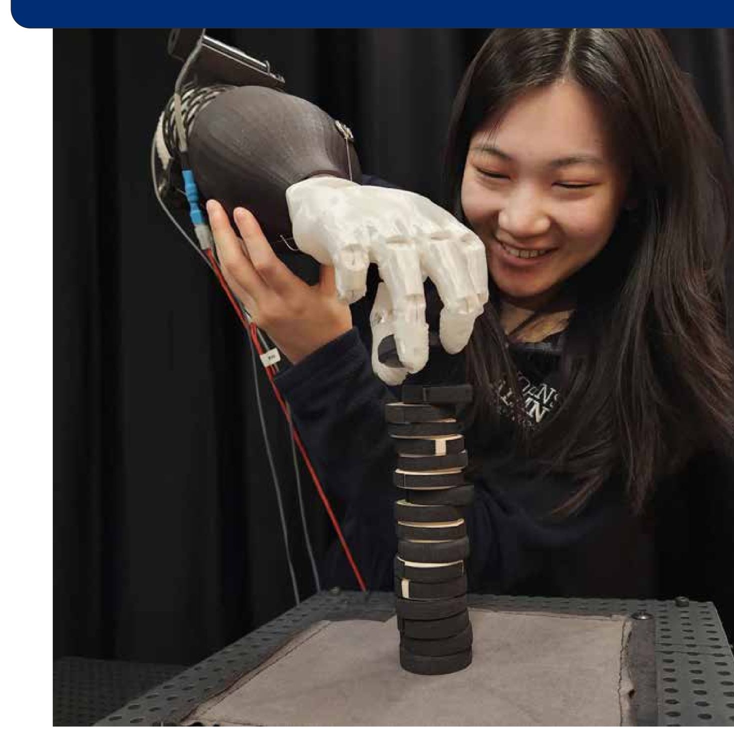


REU student projects expand on key design factors: (A) flexible, adjustable prosthetic sockets, (B) integrated haptic feedback with dynamic force estimation, (C) stiffness discrimination via pneumatic fingertips, and (D) customized flexible tendon-actuated partial hand fittings. These student projects have been essential in the continuous development and testing of the device, and have been published and presented in a variety of conference and journal venues.

Broader Impacts

We engage students and the broader community many levels including high school research internships and hands-on lab tours for middle school students. We extend this impact through outreach initiatives such as Camp Bmore, where we design custom prosthetic devices for children and families affected by cancer, and through interactive exhibits at the Maryland Science Center that invite audiences of all ages to explore prosthetic technology and human-centered design.

Results



Results of this work have been published and presented in multiple venues and can be found at the QR code above.

Conclusion and Future Work

Collectively, these findings provide strong evidence that restoring biomechanical congruence, physiology-informed impedance modulation, and state-based haptic feedback enhances dexterous performance while reducing cognitive and physical burden during human–prosthesis interaction

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