Implementation and Validation of a Data-Driven Variable Impedance Controller on the Össur Power Knee

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Abstract

Previous studies of commercial robotic knee prostheses have shown limited positive clinical results. In response, **we transferred our continuous, data-driven control algorithm from a prototype prosthesis to the Össur Power Knee™,** aiming to enhance its clinical benefits. In sit, stand, and walk experiments with four participants, **our controller allowed the Power Knee to produce clear benefits relative to users' microprocessor knees**, achieving greater loading symmetry and better walking kinematics among other clinical improvements. These outcomes replicate the successes previously observed with our prototype prosthesis, demonstrating the **hardware generalization of our control approach.**



Introduction

The Problem

- Clinical evaluations of commercialized robotic knee prostheses have produced limited positive results [1-3].
- Discrete, tuning-based control algorithms may limit performance and could explain the observed limited clinical benefits.

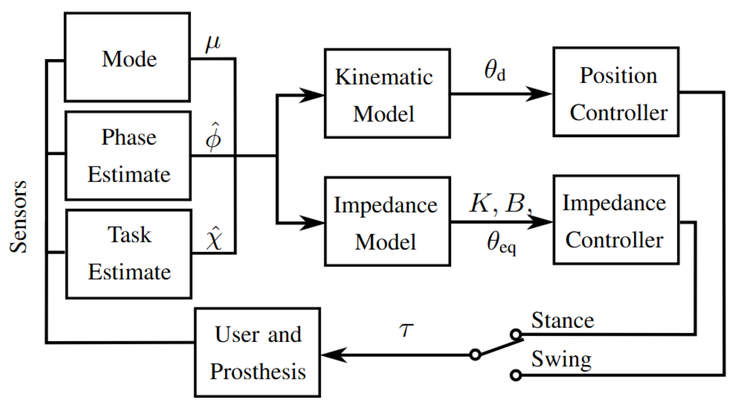
Proposed Approach

- We propose to instead use a *continuous, data-driven* controller. It has been shown to create biomimetic behaviors on a prototype robotic knee-ankle prosthesis without requiring manual tuning.
- Validation of the controller's efficacy and benefits on the Power Knee™ are required due to the substantial hardware differences (drivetrain, mass, etc.) and the lack of an actuated ankle joint.

Methods

Control Method

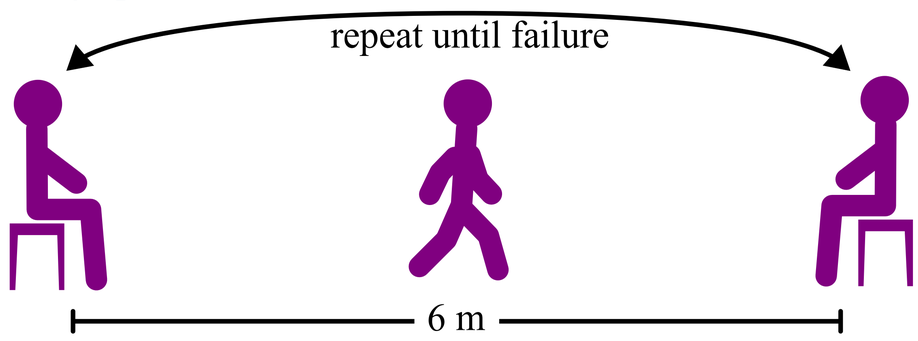
- Our continuous, phase-based controller calculates impedance (stance) and kinematic (swing) references based on models of able-bodied data. The models take inputs of mode (sit/stand vs. walk), gait phase, and task (speed), which are all estimated in real-time on the prosthesis using on-board sensors [4].



- Drivetrain compensation methods were implemented to improve the Power Knee's impedance control accuracy [5].

Experiment Design

- Participants completed laps walking between two stools at a self-selected pace with specified starting intervals. The intervals slowly increased in minimum pace until participants could not keep up. In this work, we analyze the first 70 laps, which were "liesurely" paced.

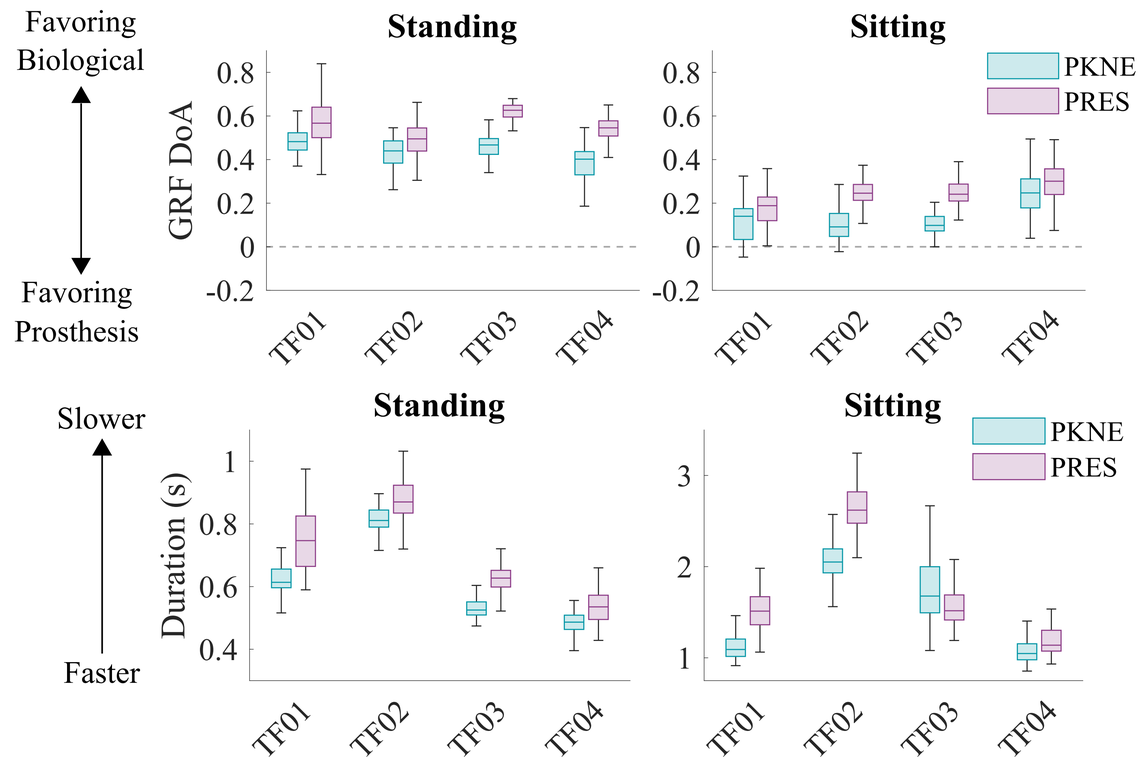


[1] Highsmith et al., 2010
[2] Wolf et al., 2013
[3] Hafner et al., 2015
[4] Best et al., 2023
[5] Best et al., 2024

Primary Results

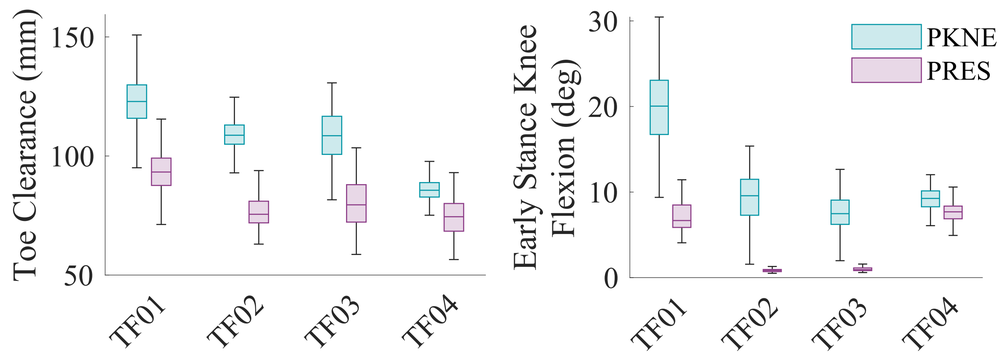
Sitting and Standing

- The Power Knee (PKNE) improved sit/stand symmetry and speed compared to prescribed microprocessor knees (PRES).



Walking

- The Power Knee also improved walking gaits with increased toe clearance and early stance knee flexion.



Conclusions

- Under phase-variable impedance control, the Össur Power Knee can produce meaningful clinical benefits over the users' prescribed passive microprocessor knees.
- Our data-driven controller can generalize across prosthesis platforms, working on both prototype and commercial devices.

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