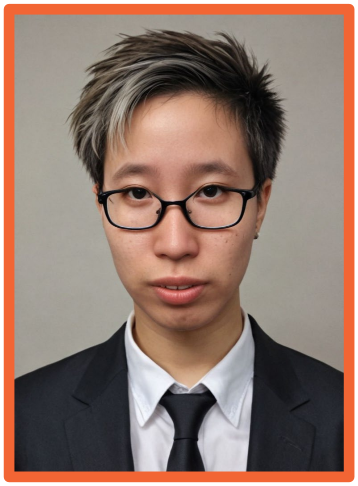
Graduate Student Research Seminar

Spring 2025

A PINN-Based Approach to Solving the Matching Condition for Energy Shaping Control in Lower-Limb Exoskeletons



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Monday, March 10th

3:00 pm (EST) – 132 Fluor Daniel Building

Abstract

Designing stable and efficient control strategies for lower-limb exoskeletons remains challenging due to the complexity of human dynamics, human-exoskeleton interactions, and the need for task-agnostic assistance. Traditional trajectory-based methods restrict volitional movement in users with partial or full limb control, limiting natural gait patterns. Energy shaping control offers an alternative, providing trajectory-free, task-invariant assistance by applying joint torques to compensate for kinetic and potential energy during gait cycles.

Under this framework, the closed-loop mass and gravity matrices, which define the system's shaped energy, are determined by solving a set of nonlinear partial differential equations known as the matching condition. In this work, we propose a Physics-Informed Neural Network (PINN)-based approach to efficiently and adaptively solve these conditions. Our method learns the mass matrix and potential energy functions directly from gait data, automating and optimizing the formulation of energy functions.

This approach eliminates the need for manual derivation or numerical matching condition solutions, significantly reducing inference time and enhancing scalability across different users and dynamic models. Additionally, we proposed an PINN structure that can account for human model uncertainties, enabling generalizable and user-specific adaptations by tuning the closed-loop system to individual weight distributions.

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