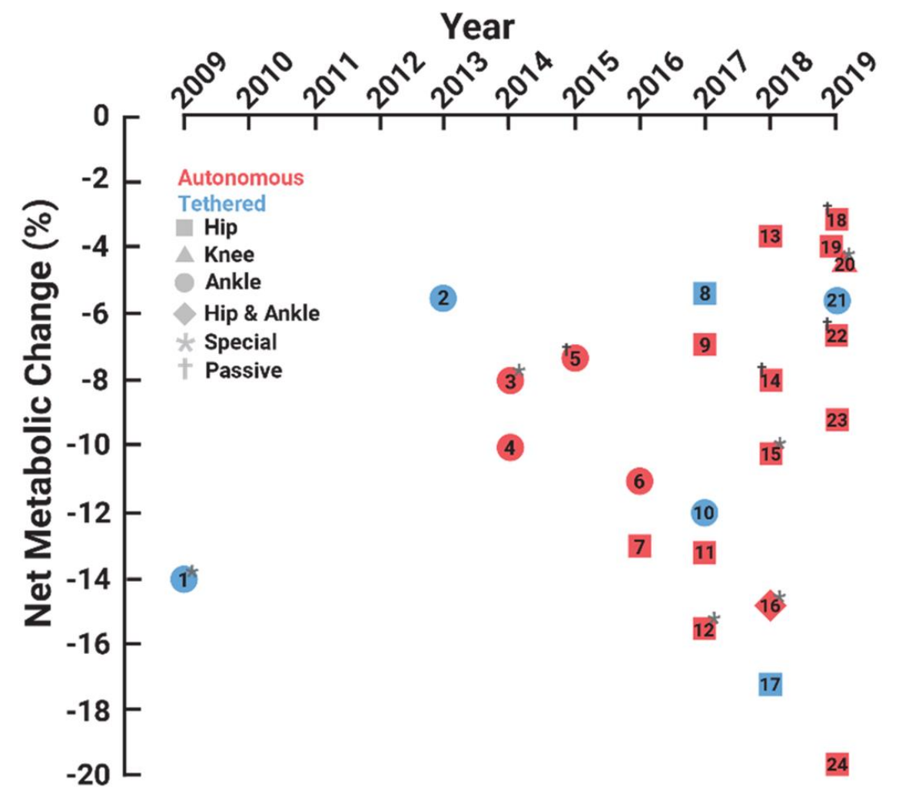
Robotic Human Enhancement Enabled through Wearable Hip Exoskeletons Capable of Community Ambulation

Aaron Young PhD

Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA
Institute for Robotics and Intelligent Machines , Georgia Institute of Technology, Atlanta, GA

Introduction

- Human hip augmentation is both novel and provides a theoretically high value proposition
- Myoelectric sensing integration in exoskeleton control may provide the needed biological catalyst to enable assistance during dynamic locomotion
- Novel controller with highly robust intent recognition enables seamless exoskeleton control for variety of activities

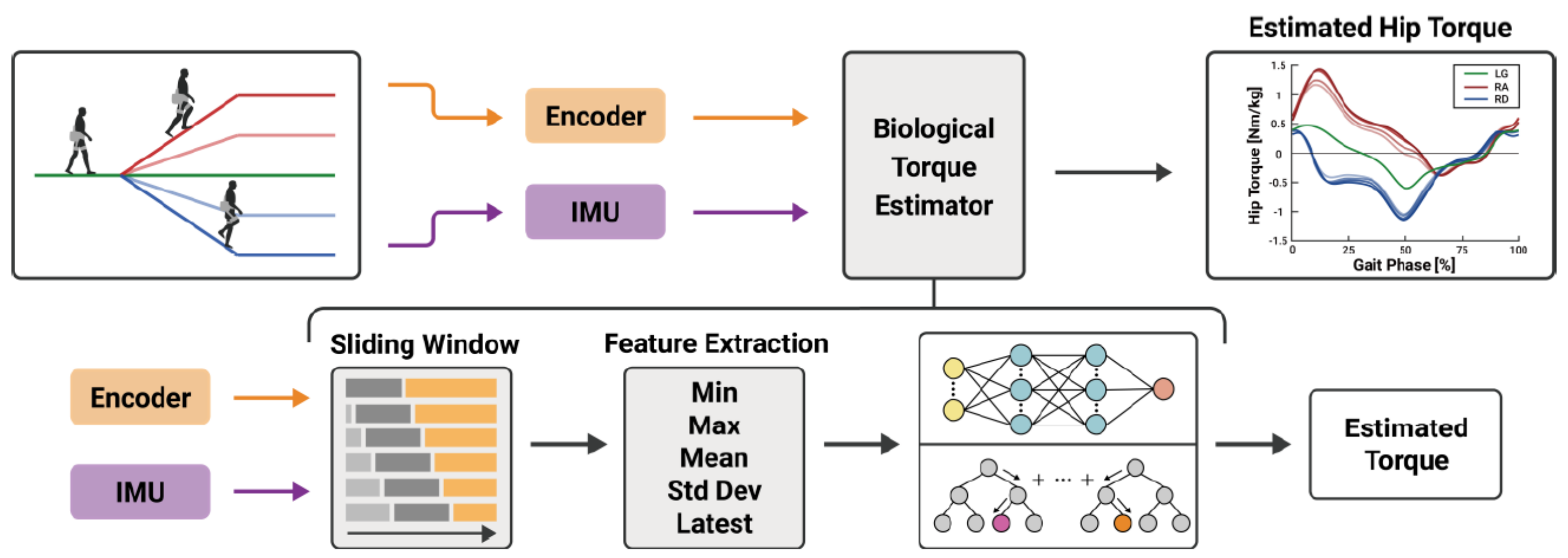


Exoskeleton studies vs. metabolic cost benefit(JNER 2020)

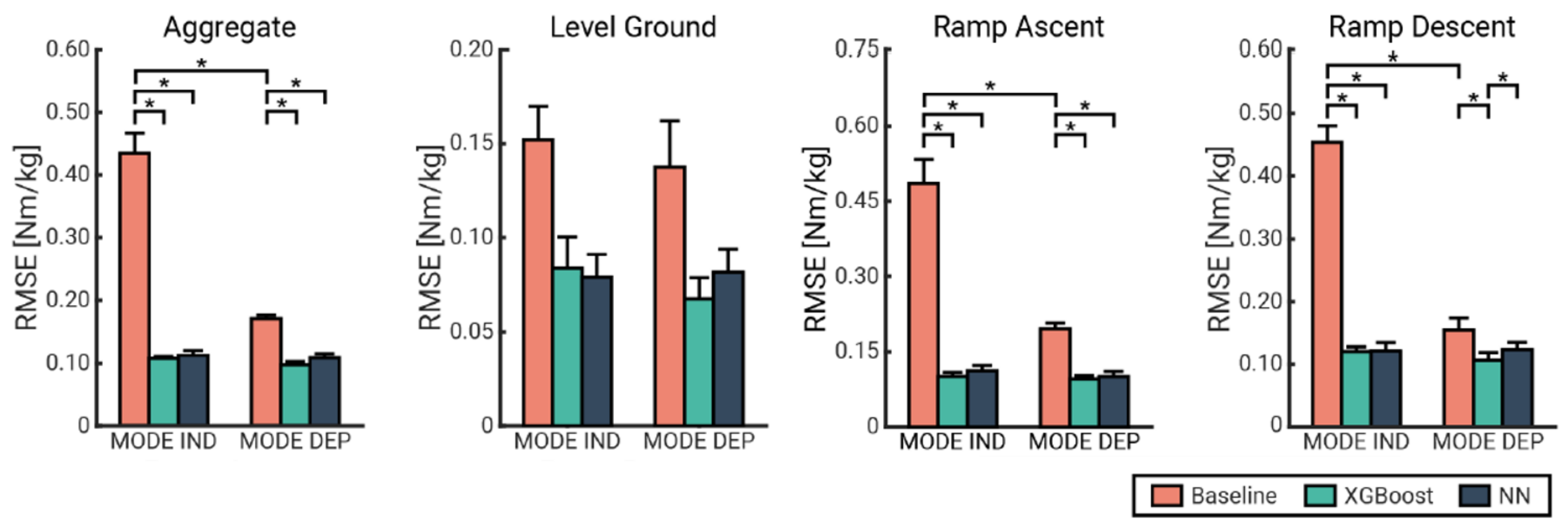
Myoelectric-based Control Approach

Objective 1: Determine the most effective strategy of providing exoskeleton hip assistance for reducing the user's effort using a novel myoelectric controller

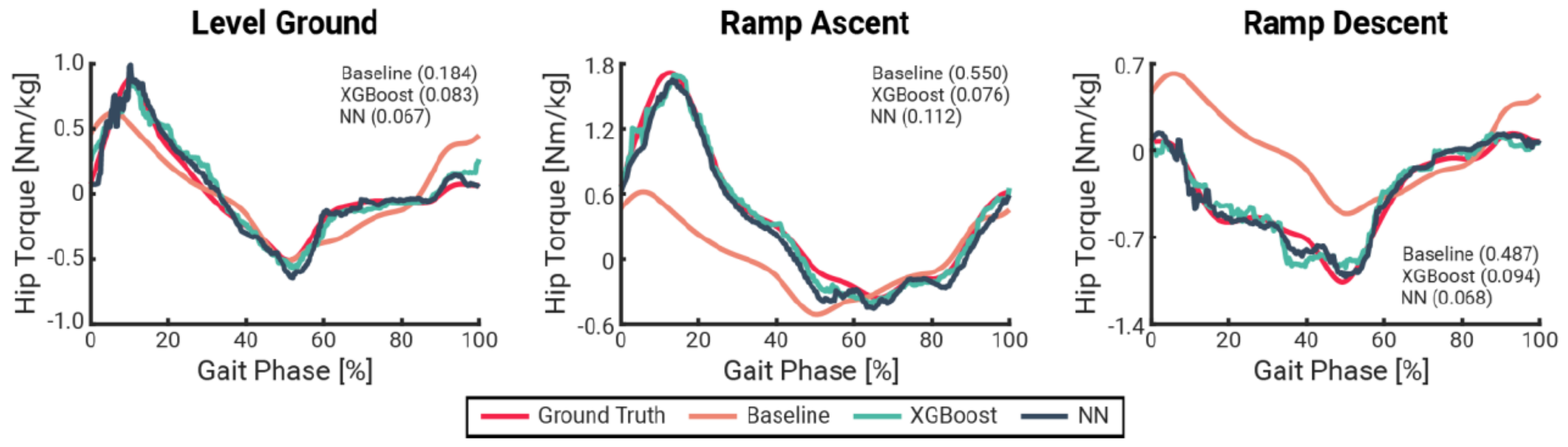
- Conventional proportional EMG signal driven controllers have limitations
- Prior exoskeleton studies showed that multiple assistance control parameters (magnitude and timing) contribute to exoskeleton performance
- Sensor fusion approach of utilizing both mechanical and EMG sensors may provide optimal exoskeleton assistance level



The analysis workflow used to estimate biological hip torque

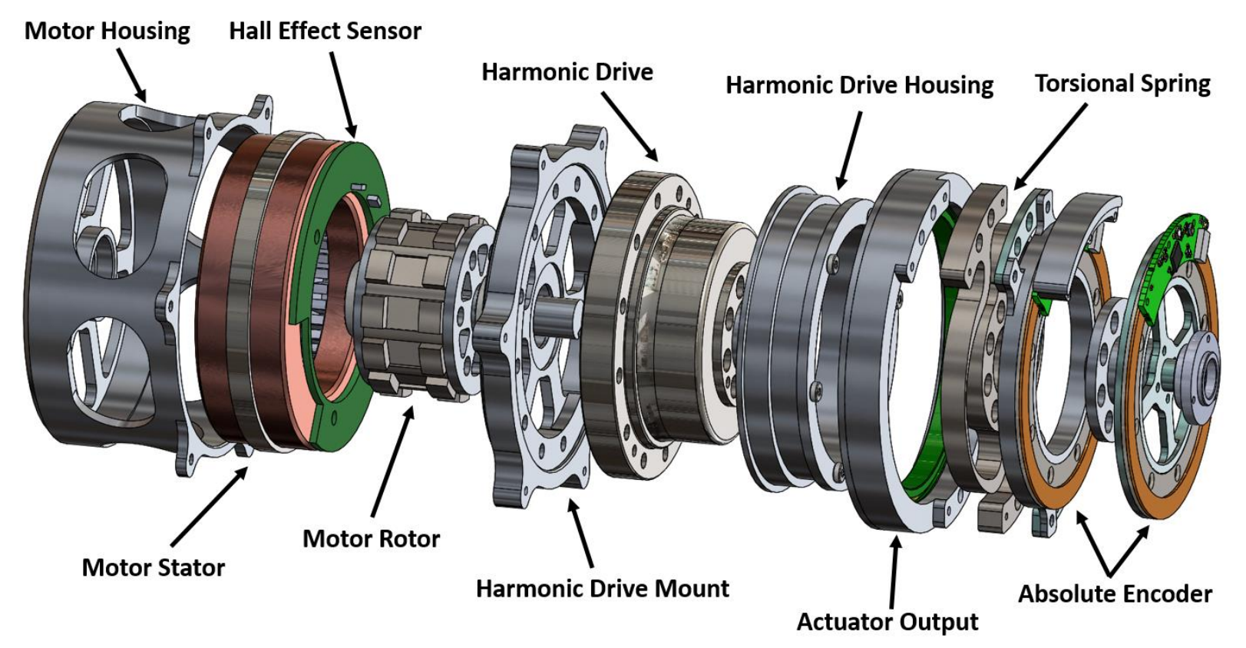


Performance of the hip torque estimation algorithms



Ground truth biological hip torque of a single step for each ambulation mode

Advanced Exoskeleton Actuator Design



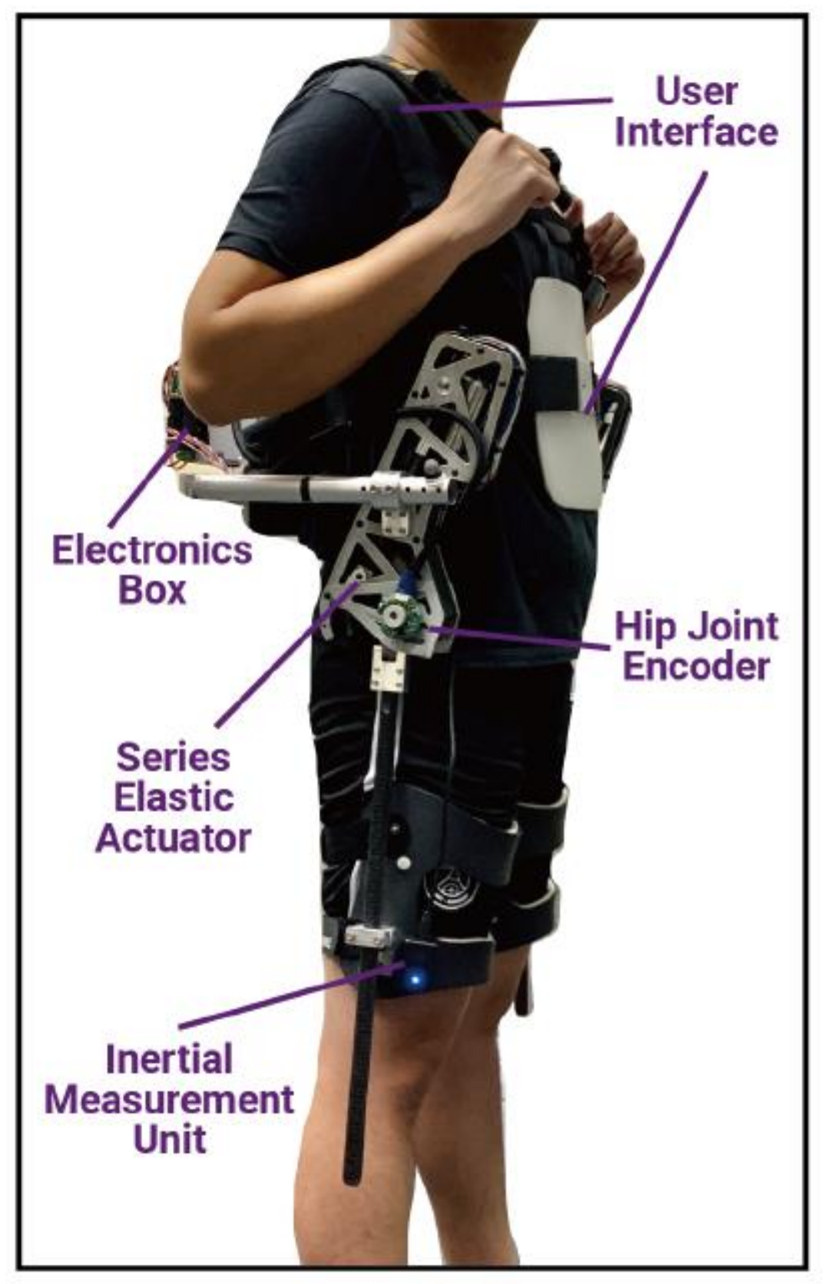
Exoskeleton Specification
Peak Torque: ~ 60 Nm
Max Continuous Torque: ~ 30 Nm
Max Speed: ~ 3 rad/sec
Torque Bandwidth: 5 Hz
Actuator Weight: 1.5 kg

Harmonic drive-based series elastic actuator

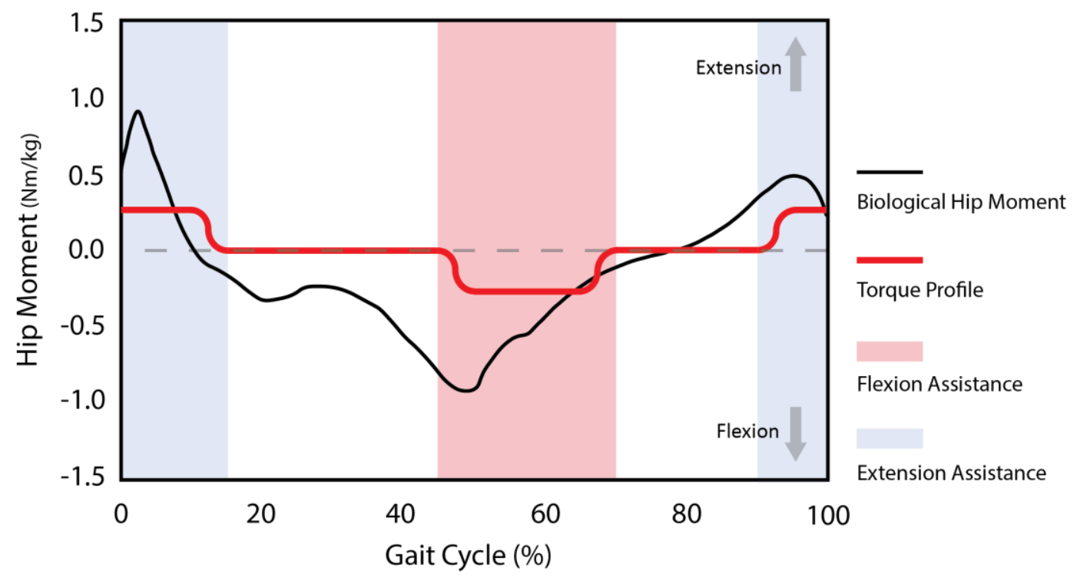
EMG Controller Performance Comparison

Objective 2: Compare the metabolic and biomechanical effects of a novel controller driven by myoelectric inputs vs a standard controller driven by kinematic inputs

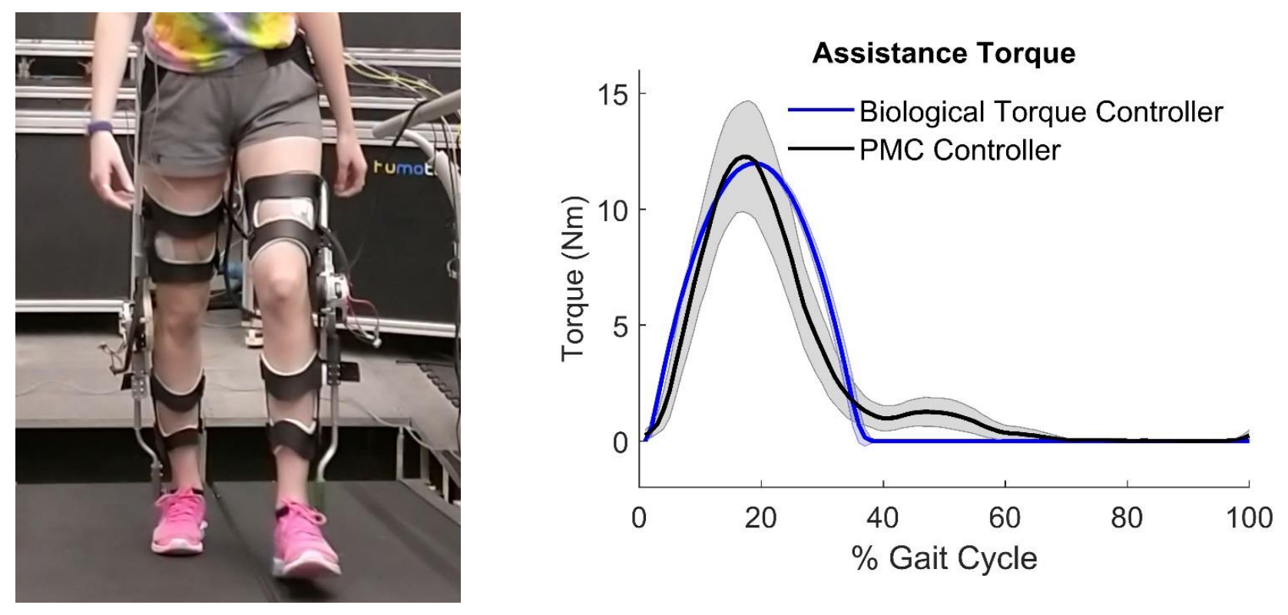
- Evaluation of EMG controller performance can be done by comparing with the state-of-the-art controller
- Both energetic and biomechanical analysis in a diverse terrains will allow better evaluate the EMG controller performance
- Testing condition can include diverse locomotion activities such as over-ground, ramps, and stairs



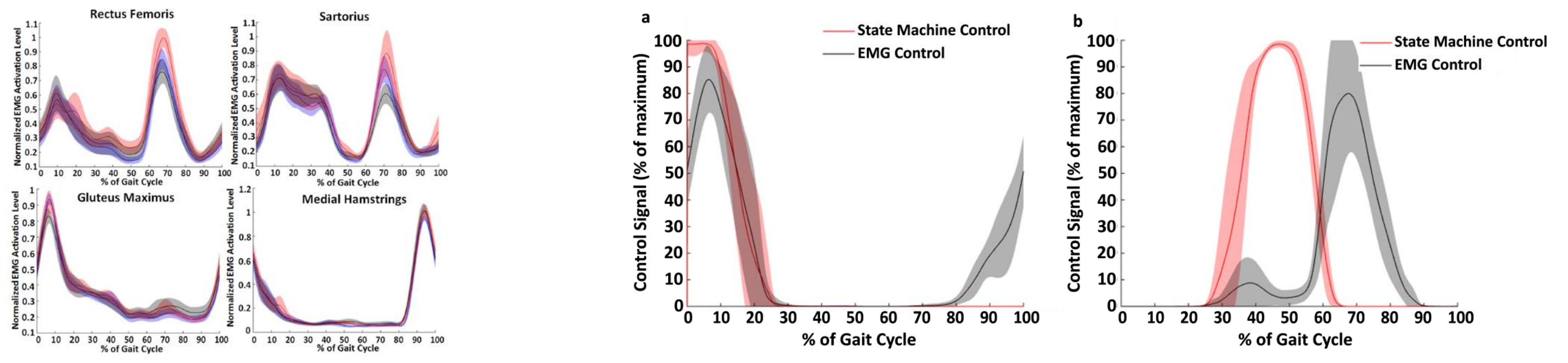
Powered hip exoskeleton



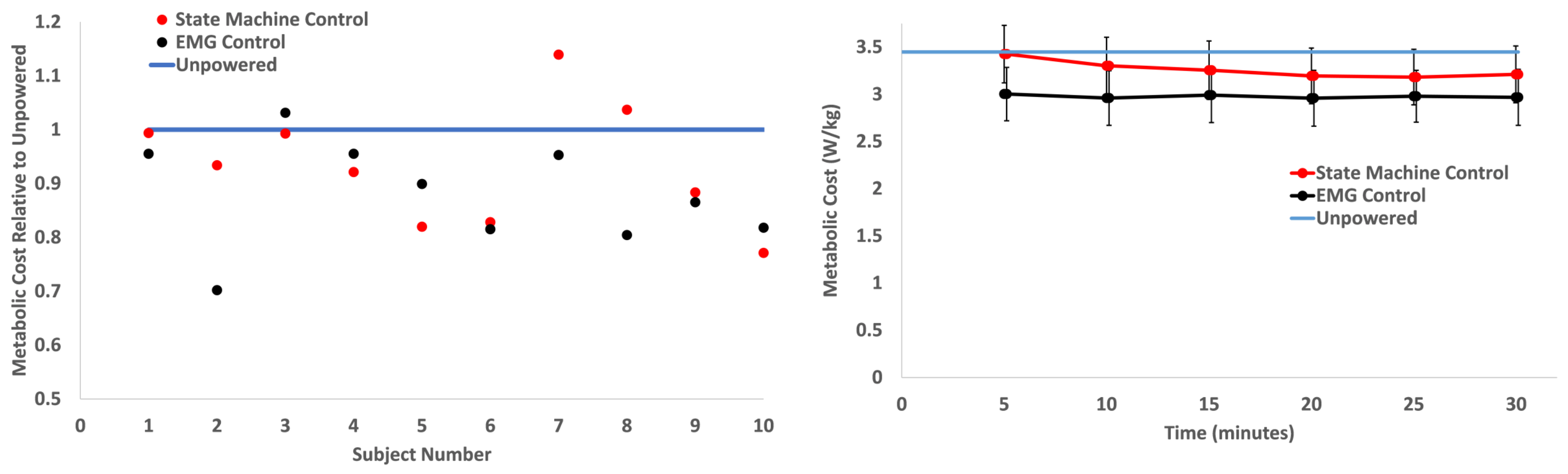
Biological Torque Control Profile



Torque controller comparison using robotic knee exoskeleton



Exoskeleton Control using Myoelectric Signals

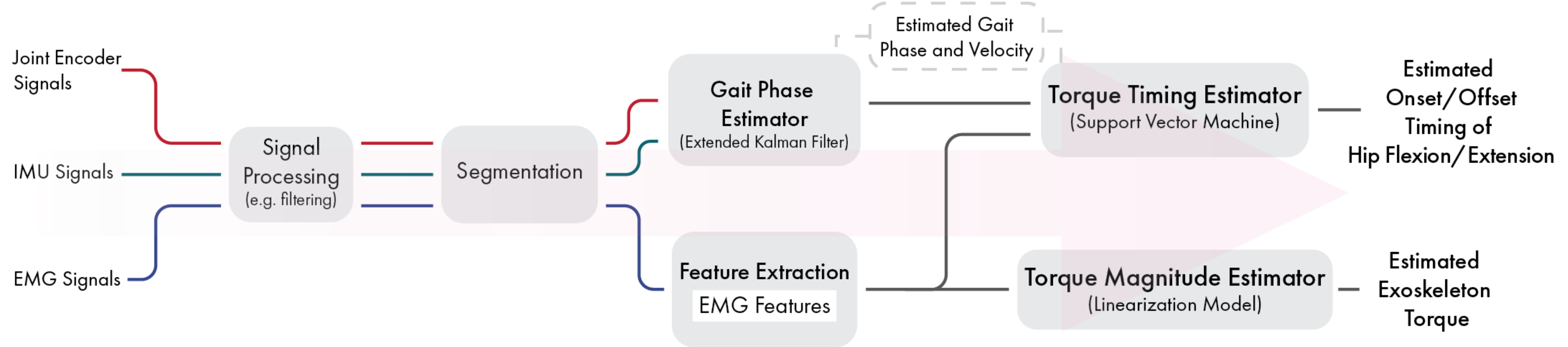


Metabolic cost comparison between EMG and standard controller

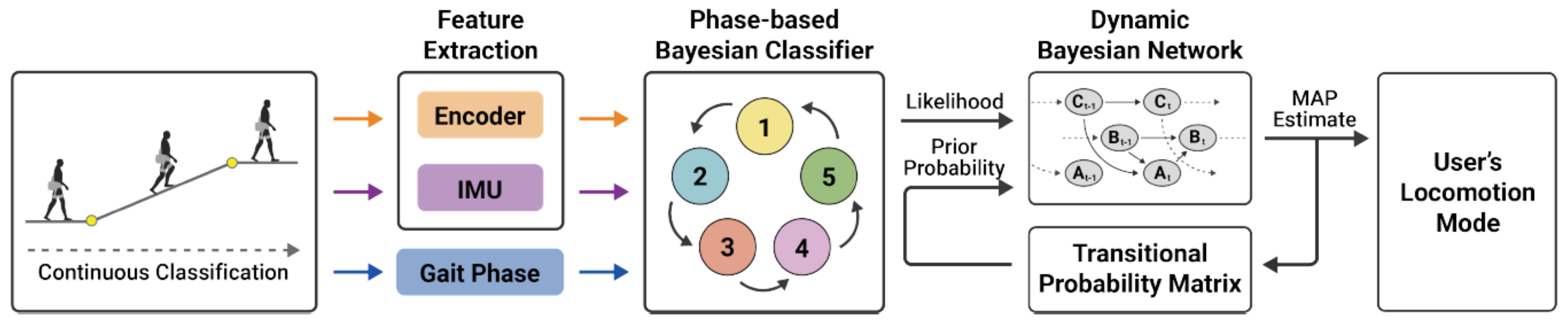
Intent Recognition using Myoelectric Sensor Fusion

Objective 3: Determine the contributions of high-level intent recognition using myoelectric information to improve control of a powered hip exoskeleton over simulated community terrain

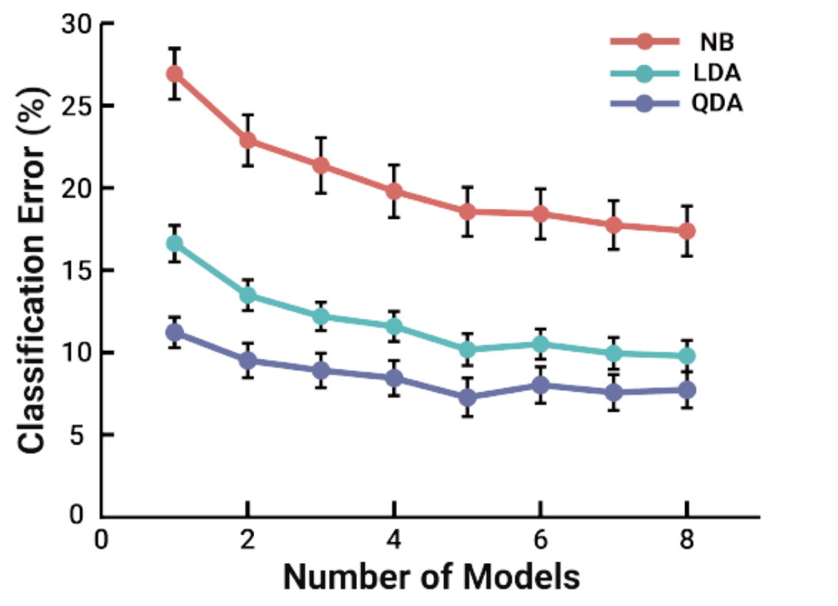
- High level intent recognition is need to transit the exoskeleton to different walking gaits in variety of locomotion modes
- Myoelectric signals and robotic sensor data will be used with machine learning techniques to classify transition between sitting, standing, level walking, stairs, ramps



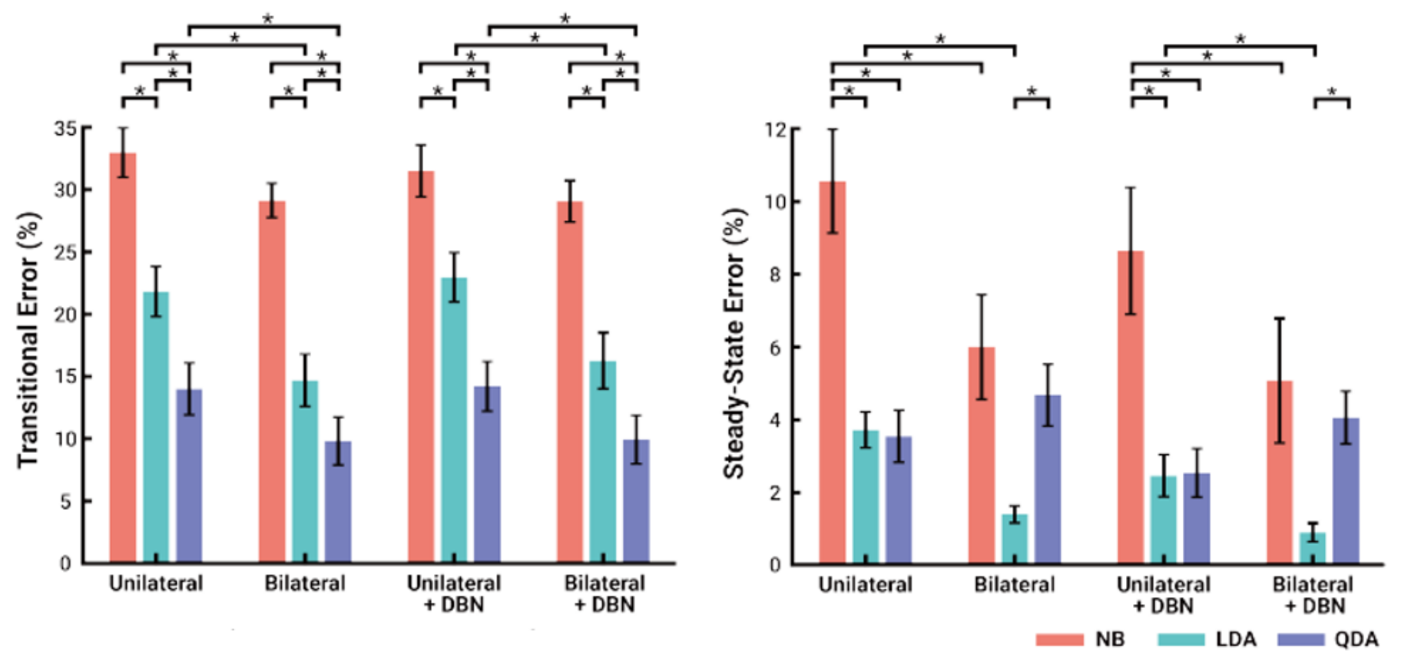
Sensor fusion strategy to control the hip exoskeleton



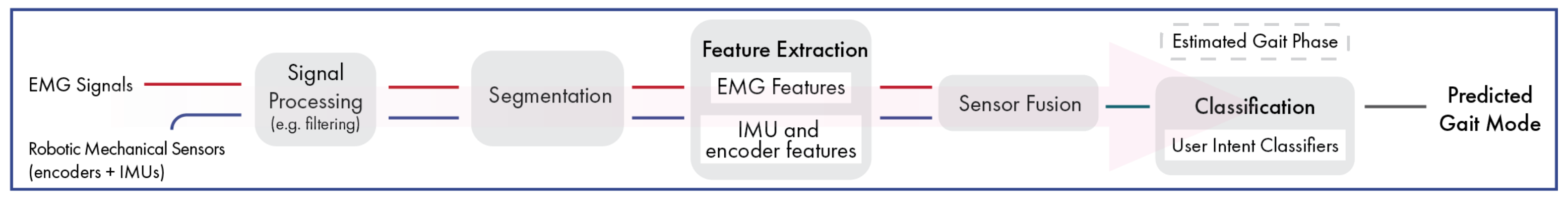
Continuous locomotion mode classification strategy



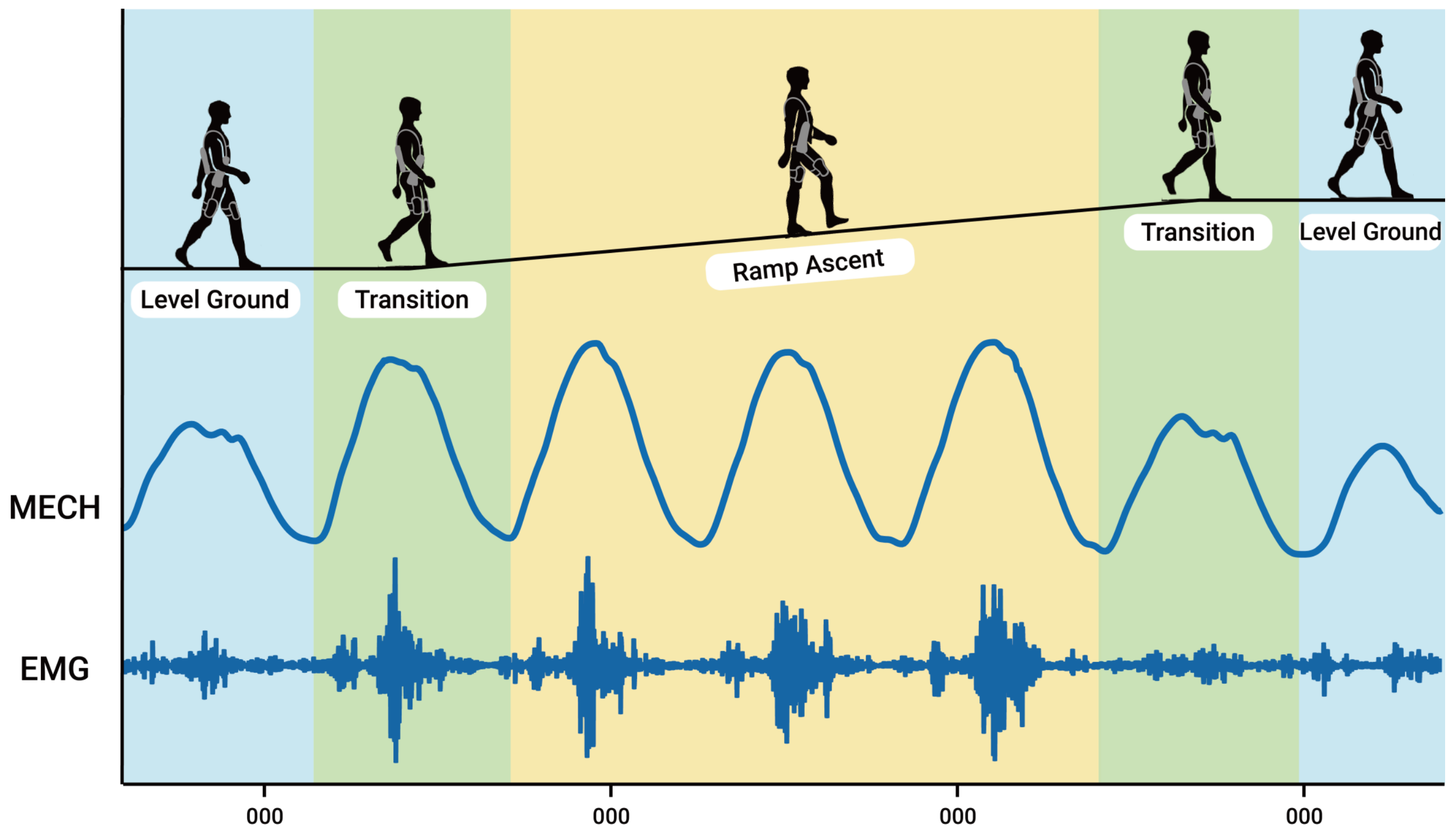
Phase dependency model sweep



Locomotion mode classifier performance



User intent recognition strategy for locomotion mode classification



Example of sensor fusion-based continuous mode classification