Abstract:
Wearable exoskeletons offer significant promise for enhancing mobility in both clinical rehabilitation and fitness contexts. However, conventional systems suffer from poor adaptability to diverse terrains and individual biomechanics, limiting their effectiveness. To address these limitations, we propose a digital twin-based framework for rapid and personalized exoskeleton control. Leveraging a markerless motion capture (MOCAP) system, our approach captures natural gait without intrusive sensors, enabling fast and accurate biomechanical data acquisition. This data informs the construction of subject-specific neuromusculoskeletal (NMS) models, which simulate realistic responses across varied motion scenarios. The synthesized physiological data is used to train a deep reinforcement learning (DRL) controller in simulation, ensuring minimal human-machine interaction and optimal biomechanical alignment. Once validated, the personalized model is deployed to a hip exoskeleton device equipped with EMG sensors and actuators for real-time assistance. Preliminary results demonstrate enhanced gait correction and reduced muscle load, particularly in pathological gait cases, while maintaining generalizability for healthy users. Our integrated pipeline sets a new benchmark for precision, adaptability, and safety in wearable robotics, with wide-ranging applications from rehabilitation to performance enhancement.

*Keywords*: Digital Twin Modeling, Wearable Exoskeletons, Neuromusculoskeletal (NMS) Personalization, Markerless Motion Capture (MOCAP), Deep Reinforcement Learning (DRL)