Deep Learning-Based Control of Pediatric Exoskeleton with Actuator Optimization for Community-Based Mobility Assistance

Sainan Zhang[1], Junxi Zhu[1], Jin Sen Huang[1], Ivan Lopez-Sanchez[1], Hao Su[1,2]

[1]Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC 27695, US

[5]Joint NCSU/UNC Department of Biomedical Engineering, North Carolina State University, Raleigh, NC 27695, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA

Lightweight and smart exoskeletons offer the potential to improve mobility in children. State-of-the-art pediatric exoskeletons are typically clinic-based since they are either tethered or portable but cumbersome and their design is often not optimized across a range of environments and users. To facilitate pediatric exoskeleton in community settings, we first proposed an actuator optimization framework that identified the optimal design parameters for both motor and transmission while minimizing the actuator mass and satisfying the output torque, speed, bandwidth, and resistance torque requirements. Guided by the optimization results, we customized a simple, lightweight actuator that met all mechatronic constraints for our portable exoskeleton (1.78 kg unilateral). Secondly, we adopted deep learning (Long Short-Term Memory) based on gait phase estimation to facilitate stable control for community use. The models accurately estimated the gait phase on irregular walking patterns (accuracy 94.60%) without explicit training in children (typically developing and with cerebral palsy). The controller results demonstrated an elevated ability to adapt to the irregular gait patterns of the child with cerebral palsy. The experimental results in the child with typical development and four healthy adults demonstrated accurate assistive torque tracking performance (accuracy 97.00%) at different walking speeds (i.e., under uncertain torque to wearers). This work presented a holistic solution that includes both hardware innovation (actuator optimization framework) and software innovation (deep learning-based control) toward the paradigm shift of pediatric exoskeletons from clinic to community setting.

Video: https://youtu.be/BndWcj_LA_8