Robotics and Autonomous Systems Thesis Defense

Variable Impedance as an Improved Control Scheme for Active Ankle Foot Orthosis

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Abstract

The human ankle is a critical joint required for mobility and stability of the body during static and dynamic activity. Absence of necessary torque output by the ankle due to neurological disorder or near-fatal injury can severely restrict locomotion and cause inability to perform daily tasks. Physical Human-Robot Interaction (pHRI) has explored the potential of controlled actuators to positively impact human joints and partly restoring the required torque and stability at the joint to perform a task. However, a trade-off between agility and stability of the control technique of these devices can reduce complete utilization of the performance to create a desirable impact on human joints. This research focuses on two control techniques of an Active Ankle Foot Orthosis (AFO) namely, Variable Stiffness (VS) and Variable Damping (VD) controllers to modulate ankle during walking. The VS controller is active during the stance phase and is used to restore the ankle trajectory of healthy participants that has been altered by adding dead-weight of 2 kgs. The VD controller is active during terminal stance and early-swing phase and provides augmentative force during push-off that results in increased propulsion and stabilizes the ankle based on user-intuitions. Both controllers have a positive impact on Medial Gastrocnemius (GAS) muscle and Soleus (SOL) muscle which are powerful plantar-flexors critical to propulsion and kinematic properties of ankle during walking. The VS controller has recorded 8.07% decrease in GAS and 8.96% decrease in SOL muscle activity during stance phase amongst participants while decreasing mean ankle position error by 19.69% and peak ankle position error by 48.06%. The VD controller demonstrated 28.4% decrease in GAS muscle and 21.7% decrease in SOL muscle activity during push-off amongst the participants while increasing the range-of-motion (ROM) by 6.74%. Comprehensively, the study has shown a positive impact on ankle trajectory and the corresponding muscle effort at respective stages of the controller activity.

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