Robotics and Autonomous Systems Thesis Defense

Variable Impedance Control for pHRI: Impact on Stability, Agility, and Human Effort in Controlling a Wearable Ankle Robot

School for Engineering of Matter, Transport and Energy

James Arnold

Advisor: Hyunglae Lee

Abstract

This paper introduces a variable impedance controller which dynamically modulates both its damping and stiffness to improve the trade-off between stability and agility in coupled human-robot systems and reduce the human user's effort. The controller applies a range of robotic damping from negative to positive values to either inject or dissipate energy based on the user's intent of motion. The controller also estimates the user's intent of direction and applies a variable stiffness torque to stabilize the user towards an estimated ideal trajectory. To evaluate the controller's ability to improve the stability/agility trade-off and reduce human effort, a study was designed for human subjects to perform a 2D target reaching task while coupled with a wearable ankle robot. A constant impedance condition was selected as a control with which to compare the variable impedance condition. The position, speed, and muscle activation responses were used to quantify the user's stability, agility, and effort, respectively. Stability was quantified spatially and temporally, with both overshoot and stabilization time showing no statistically significant difference between the two experimental conditions. Agility was quantified using mean and maximum speed, with both increasing from the constant impedance to variable impedance condition by 29.8% and 59.9%, respectively. Effort was quantified by the overall and maximum muscle activation data, both of which showed a ~10% reduction in effort. Overall, the study demonstrated the effectiveness of the variable impedance controller.

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Zoom Link: https://asu.zoom.us/j/84109050977