Balance Enhancing Controller for an Ankle Exoskeleton

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Summary

Physical therapy has had success in improving factors that correlate with balance deficits and fall risk.[1] However, there is potential for further improvement using robotic devices. While a significant amount of research has been conducted using wearable robots such as exoskeletons to help patient populations walk with lower energy use, little work has been conducted using these devices to improve human balance.
Our lab previously developed balance-enhancing prosthetic limbs, and we will leverage insights from this work to develop stabilizing exoskeletons.[2][3]

We propose to develop a step-by-step ankle push-off torque control scheme for ankle exoskeletons and to perform a series of experiments to test feasibility of the approach in stabilizing older adults. If effective, the proposed approach could be integrated into untethered and low profile exoskeletons that older adults could wear in their daily lives. This could reduce fall risk and improve quality of life.

Introduction

Previous studies from our lab have shown that: 1. Appropriate step-by-step control of ankle push-off work can be used to correct both fore-aft and mediolateral center of mass state deviations. 2. Commanding more push-off work on steps when the mediolateral velocity of the center of mass is lower than usual at the time of contralateral heel strike results in human stabilization; 3. Commanding the opposite results in destabilization; and 4. Balance enhancement could be reasonably measured in terms of balance-related metabolic cost. Since falls during walking can be described as the inability to respond effectively to "loss of balance," researchers have begun to explore balance using controlled perturbations. [4] Our lab has also recently designed a cable-driven system that can apply a more diverse variety of perturbations that simulate trips, slips, and bumps. Using this device, we would be able to provide controlled balance disturbances that are unpredictable to the participant and that alter the center of mass position and velocity relative to the stance foot, and simultaneously stabilize them using the balance-enhancing ankle exoskeleton controller.

Methods

Ankle exoskeleton push off torque will be varied on each step in ways expected to stabilize the individual. Average ankle push off torque (known to affect effort) will be kept constant. We hypothesize that commanding more ankle push off torque when the mediolateral velocity of the center of mass is lower than usual at the moment of contralateral heel strike will result in stabilization. To measure changes in stabilization, we will measure step width variability. We expect that improved stabilization will result in a reduction in step width variability. We are beginning tests soon and hope to have interesting results to discuss at the conference this summer.

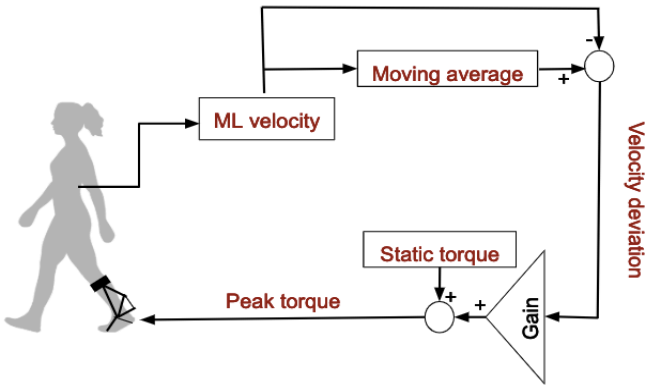

Figure 1: High-level controller used to modulate ankle push-off torque.

References

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