Heuristic based control for hip-knee-ankle exoskeleton assistance

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Summary

Exoskeletons have the potential to augment walking, running or carrying a load; however, finding effective strategies has proven to be difficult. Recently, researchers have found useful assistance by adjusting parameters based on biomechanical response. For example, a heuristic based strategy that slowly adapted bilateral plantarflexion assistance based on muscle activity reduced metabolic cost by 22%. Assistance at the hip, knee and ankle could lead to larger metabolic reductions as all three joints significantly contribute to total biological power during walking and running. Furthermore, this approach should scale well to increasing the number of actuated joints. To facilitate assistance exploration at all three joints, we built a hip-knee-ankle exoskeleton emulator with performance capabilities that match uphill running. We will use this device in combination with the heuristic based control strategy to discover effective exoskeleton assistance for walking and running.

Introduction

Exoskeleton assistance could drastically improve the mobility of a wide range of people, from those with walking impairments to first responders. Recently, human-in-the-loop optimization has discovered useful exoskeleton assistance strategies at the ankle or hip [1, 2]. In addition, a heuristic based control strategy that slowly adjusts assistance based on biomechanical changes of the user found effective assistance for bilateral ankle exoskeletons [3]. Assisting the hips, knees and ankles could be more effective than assisting one or two joints since all three joints significantly contribute to total biological power in walking and running [4]. However, assistance at all three joints could increase the number of parameters needed for optimization therefore increasing the time for the algorithm to converge. The heuristic based control strategy would allow discovery of assistance at all three joints without drastically increasing the time to converge. Therefore, we will use a heuristic based control strategy in combination with a bilateral hip-knee-ankle exoskeleton emulator [5] to discover personalized hip-knee-ankle assistance.

Methods

We will develop effective assistance strategies for a bilateral hip-knee-ankle exoskeleton emulator [5, Fig 1]. Through 10 off-board motors and a Bowden cable transmission, this device can provide torque in hip flexion, hip extension, knee flexion, knee flexion, and ankle plantarflexion. It matches the performance capabilities of uphill running. This device can fit a wide range of people through length and width adjustability as well as a variety of boot sizes. It also allows the user to move in unactuated directions through planar carbon fiber struts.

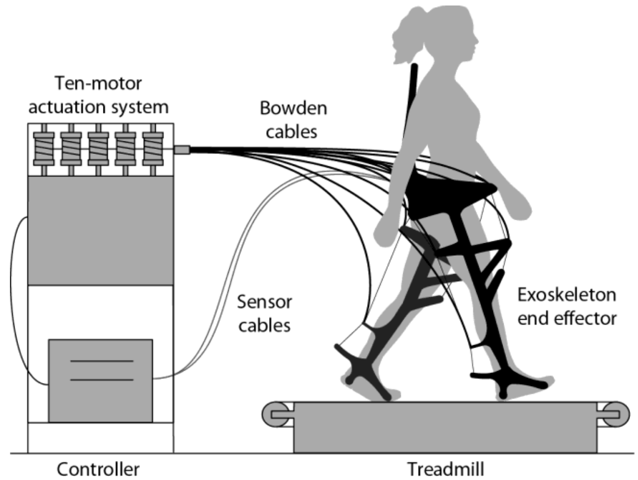

Figure 1. Schematic of the exoskeleton emulator system.

We will adapt the previously developed heuristic based control strategy [3, Fig. 2]. This strategy gradually builds the assistive torque to allow for coadaptation of the device and the user. Each step, the assistive torque adjusts to decrease agonist and antagonist muscle activity while maintaining minimal kinematic changes. We will expand this controller to assist the hip, knee and ankle.

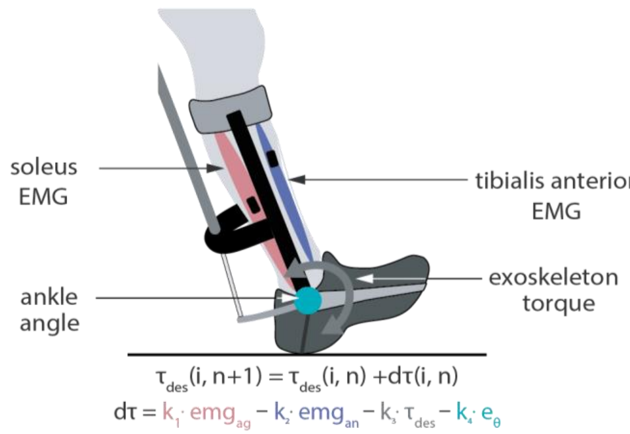

Figure 2. Overview of the heuristic based controller [3].

Results and Discussion

We are just beginning experiments, and we plan to have preliminary results by June.

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