Developing a Surface-Matching Controller Using an Ankle-Foot Prosthesis Emulator

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***Abstract*—More than half of individuals with a lower-limb amputation list an inability to walk on uneven terrain as a major limitation. We are developing a surface-matching controller on a prosthesis emulator that will reduce the magnitude of disturbances resulting from uneven surfaces. This is accomplished by sensing the ground height at three locations on the emulator then adjusting the neutral angles of the emulator to compensate for the potential height differences. To test this controller, we have modified a consumer treadmill to create an uneven walking surface. We will present experimental results demonstrating the efficacy of the controller.**

Introduction

Advancements in prosthetic feet have enabled lighter, stronger designs that return more energy on each step, yet uneven terrain such as gravel and wooded areas still provide a signficant challenge to individuals with lower limb amputations. Compared to the non-disabled population, affected individuals walk slower and with a larger energetic penalty [1], [2], with about 60% of the affected population citing an inability to walk on uneven terrain as a major limitation [3]. To address this need, commercial prosthetic feet have adopted split-toe designs, but these solutions do not fully restore the ability to walk on uneven surfaces. Our work focuses on developing a controller on a prosthesis emulator that will reduce the magnitude of disturbances resulting from uneven surfaces, referred from here on as a surface-matching controller.

Methods

In order to develop a surface-matching controller, we need a systematic method of creating an uneven surface for the user to walk on. To do so, we attached wooden blocks of varying heights onto the belt of a consumer treadmill, similar to an existing design [4]. We simulated several terrain patterns in MATLAB to analyze the frequency and magnitude of expected disturbances. We decided upon a design that was simple to fabricate, provided a varied combination of sagittal and frontal plane disturbances, and was designed to be difficult for the user to predict or avoid upcoming disturbances.

The surface-matching controller was implemented on an existing ankle-foot prosthesis emulator that is equipped with three independently actuated digits [5]. The controller actuates these digits through the different phases of gait in order to conform to the walking surface. The controller is based on a state machine, cycling between heel strike, stance, and swing phases. Upon heel strike, the controller rotates the two forefoot digits towards the ground in order to sense the terrain. After both digits have made contact, angular stiffness of the two forefoot digits increases in order to support the body for the remainder of stance. During swing, all three digits raise up to provide additional swing clearance.

We are currently conducting an experiment comparing participants' prescribed feet and the prosthesis emulator. We will be comparing metabolic rate as well as kinematic outcomes including step width and variability, step length and variability, and movement of the pelvis, torso, and arms. We expect to have some preliminary data to share by the conference date.

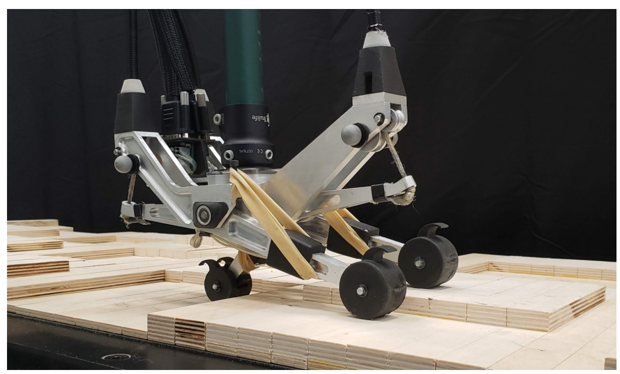

Fig. 1. The prosthesis emulator adapting to an uneven surface.

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