Active Knee Assistance For Prevention of Slip-Induced Falls During Human Walking

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Abstract— Slip and fall is a major cause of injury in the elderly and outdoor workers. Slip often leads to a fall, when a subject steps on a slippery surface and does not realize that the front foot is slipping, while continues to swing the trailing foot forward. This leads to the subject's center of mass being positioned posterior to the base of support formed by both legs and backward fall occurs. This paper presents the development of a wearable knee device aiming to assist and prevent slip-and-falls. The device assists by extending the knee of a trailing leg pushing against the ground. This extends the base of support and helps with the slip recovery.

Keywords— slip and fall, slip balance recovery, wearable knee assistive exoskeleton, compressed gas actuation system

I. INTRODUCTION

Slips and trips that lead to falls, pose a significant risk of injury across all populations [1]. Foot slip is one of the major causes for falls especially among adults over 65 years [1]. Preventing slip-induced falls and associated injuries would reduce economic and societal costs and improve life of those experiencing such events.

In our previous works [2,3], we developed a rapid slip detection system and slip-and-fall prevention assistive device (ROKAD). Slip detection algorithm can detect foot slip during human walking shortly after the slip onset (60 msec), which is much faster than the human reaction capabilities. The slip detection system uses a set of wearable IMUs that attach on the shank, thigh and heel. The approach of the ROKAD device was to provide assistive knee torque to the slipping leg, which requires large torque capabilities and heavy, powerful actuators.

The goal of this study was to design a lightweight knee exoskeleton device to assist the elderly and certain high-risk outdoor workers to prevent falls during slip occurrence. Compared to the ROKAD device in [3], the working principle is different, due to providing assistive torque to the knee of the swing leg instead of the stance leg.

II. KNEE ASISTIVE EXOSKELETON DESIGN

A. Fall Prevention Strategy

Figure 1 presents the prototype of the knee assistive exoskeleton. The device assists with the knee extension of the trailing leg during slip perturbation. The purpose of the device is to extend the knee during swing phase and therefore immediately increase base of support (BOS). Increased BOS, with the instantaneous center of mass (COM) lying inside the BOS area, results in increased dynamic stability of the human and helps with successful balance recovery to prevent falls.

B. Knee Assistive Exoskeleton Prototype

The device consists of a lightweight knee brace driven by Bowden cables. The actuator and electronics are located in a backpack not to hinder walking gait. The main components of the device are shown in Fig. 1. The device is controlled using Arduino that integrates the IMU-based slip detection system [2] and activates the device based on the algorithm's output.

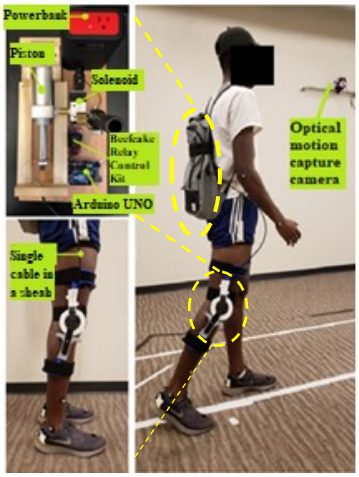

Fig. 1. Knee asistive exoskeleton prototype.

III. RESULTS AND DISCUSSION

Bench testing of the device showed the device can provide assistive torque and extend knee for 60 deg (~max knee angle) in less than 0.14 sec. This is sufficient for assisting human during slip-and-fall. We are currently testing the device for use on human subject to test various assistive control strategies.

REFERENCES

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