DYNAMIC ANALYSIS OF WALKING WITH A POWERED STANCE-CONTROL KNEE-ANKLE-FOOT ORTHOSIS

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Introduction

The analysis and design of powered exoskeletons and orthoses that assist human gait is an open field of research that covers the areas of biomechanics, robotics and neurorehabilitation. Those devices are thought to help patients with disabilities (caused by spinal cord injuries, acquired brain damage, etc.) and are also useful to rehabilitate lower limb muscle control up to a certain degree.

In this work, a powered lower limb orthosis aimed at assisting incomplete spinal cord injured (SCI) subjects is presented. The target patients are classified with levels C or D in the ASIA (American Spinal Injury Association) impairment scale. They are able to control hip flexor muscles, but have partially denervated muscles actuating the knee and ankle joints. The kinematics and metabolical cost of their gait can be improved by means of active stance-control knee-ankle-foot orthoses (SCKAFO) [Yakimovich *et al*, 2009].

The inverse dynamics of the orthosis-assisted locomotion in a healthy individual is analyzed in order to understand the combined subject-orthosis actuation and human adaptation to such devices.

Methods

The SCKAFO shown in Figure 1 is tested in a lab environment. The design of this device was presented in [Font-Llagunes *et al*, 2011]. It consists of a compliant ankle joint that limits plantar flexion, along with a powered knee unit that locks flexion during stance and controls the flexion-extension motion during swing. This is accomplished by means of a controllable locking system and a motor. The orthosis is equipped with plantar sensors and encoders for its control.

The gait of a healthy subject walking with and without the orthosis is captured by 12 Natural Point OptiTrack FLEX:V100R2 cameras sampling at 100 Hz, that detect 36 passive markers attached to the human body. The foot-ground contact forces and torques are measured by two AMTI AccuGait force plates. A 3D whole-body model of the subject-orthosis system has been developed in mixed (natural and relative) coordinates to solve the inverse dynamics problem. The model incorporates the subject's body segment parameters (BSP), as well as the orthosis geometric and inertial parameters.

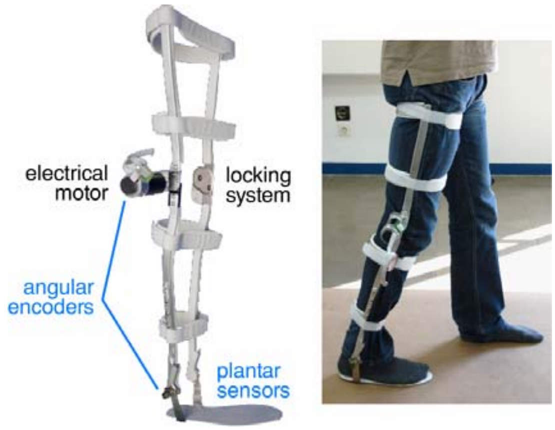

Figure 1: Active orthosis (left) and subject wearing the orthosis (right).

Results

From the motion data, the BSP and orthosis parameters, and the force plate measurements, the net torques at the knee and ankle joints are calculated following the inverse dynamics procedure explained in [Cuadrado *et al*, 2011]. Then, we determine how the net joint torques are shared between the musculoskeletal system and the orthosis by experimentally measuring the external assistance torques at the knee and the ankle.

The obtained torque and kinematic patterns are compared to those of normal unassisted walking, so as to validate the hypothesis of invariant torque patterns when walking with or without robotic assistance [Kao *et al*, 2010].

Discussion

The work presents a powered SCKAFO aimed at assisting SCI patients. The inverse dynamics of the gait of a healthy subject wearing the orthosis is analyzed and the results compared to those of normal walking. The subject-orthosis force sharing problem is also investigated to better understand the subject's motor adaptation to robotic assistance.

References

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