Human Motion Analysis of a Healthy Subject Wearing Active Orthoses

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Introduction

The use of active orthoses has become a powerful tool in medical rehabilitation[1]. Proper operation depends on the coordination of different tasks, such as mechanical and controller design. Since these devices are highly customized to the patient, simulation can help to streamline their development.
The objective of this work is to present the progress of an ongoing national project carried out by three Spanish universities (UEx, UPC and UDC), aimed at building an innovative prototype of active orthosis for gait assistance and to develop a computer simulation tool to virtually test this type of devices.

Materials and methods

As a starting point for the project, a system for gait analysis of both healthy subjects and spinal cord-injured subjects wearing active orthoses[2] has been developed: 12 OptiTrack Flex:V100 cameras are used to track the trajectories of reflective markers placed at anatomical landmarks, 2 AMTI AccuGait force plates to measure the foot-ground reactions, and 18 B&L Engineering electrodes for electromyography (EMG) measurements. The hardware synchronization is achieved by means of a National Instruments data acquisition system, acting as a master device. All the devices are controlled by an in-house developed software.
The active orthosis prototype[3] is a Stance-Control Knee-Ankle-Foot Orthosis (SCKAFO). To assist the swing motion, a Maxon EC-45 flat motor has been installed on the outer knee articulation of the leg brace. It is controlled by the commercial EPOS2 interfaces with a position control that uses a modified PID controller with acceleration feed-forward. Force sensing resistors are placed on the foot plate to detect the ground contact. The operation of the active orthosis is integrated on the previously mentioned in-house software, and the data acquisition is also synchronized with the remaining elements.
A computational model of the combined system human-orthoses has been developed in mixed coordinates (a total of 228). It possesses 18 bodies connected by spherical joints and 57 degrees of freedom. The orthoses inertias are introduced in the model by altering the inertia properties of the adjacent human segments, while the provided motor torques are calculated from the controller equations and are used as an input of the model. An inverse dynamic analysis (IDA) can be performed to obtain the motor torques exerted by the subject. Moreover, it is possible to obtain muscular forces from these torques[4] and to compare them with the recorded and processed EMG signals.

Results and discussion

An experimental trial has been carried out on a healthy female (1.60m, 50kg) wearing the active orthosis prototype in both legs. The subject walked along the capture volume of the infrared cameras and over the force plates, while trajectories of the markers, EMG signals, ground reaction forces, DC currents of the motors and angular positions of the knees were recorded. Figure 1 shows the comparison between the reaction forces and moments obtained from IDA and measurements. The results are in good correlation considering the associated errors, even though the gait analysis system is built on low-cost equipment.

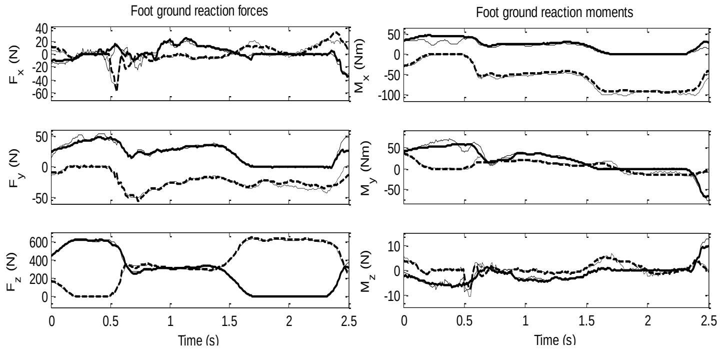

Fig. 1: Ground reaction forces and moments (solid: right foot, dotted: left foot; thick: force plates; thin IDA).

Conclusion

The IDA of assisted gait can be of a great help for the assessment of active orthosis operation as well as for the mechanical and control design. Using this tool, the specialist can compare the net joint torques during gait for able-bodied and SCI subjects wearing both passive and active orthoses, analyze the influence of different control strategies, study the SCI subject adaptation process and understand the complex muscular-orthosis co-actuation. To that end, further analysis of the recorded EMG signal is required.

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