

MUSCLE FORCES ADAPTATION IN ASSISTED WALKING USING A POWERED SCKAFO

F. Romero (1), J. Alonso (1), S.H. HosseinNia (2), B. Vinagre (2), J.M. Font-Llagunes (3)

1. Dept. of Mechanical Engineering, Energetics and Materials, University of Extremadura, Spain; 2. Dept. of Electrical, Electronic and Automation Engineering, University of Extremadura, Spain; 3. Universitat Politècnica de Catalunya, Spain

Introduction

In the last few years, considerable effort has been devoted to the design of active orthoses to assist human gait. However, few works address the study of muscle forces adaptation in assisted walking [Cain, 2007]. This issue is related to the well known redundancy problem in biomechanics, which is a challenging topic for dynamic simulation and control. In a previous work [Alonso, 2011], the authors used a simple approach to solve the load sharing problem in the combined actuation of the human-orthosis system, with the fundamental hypothesis that joint torques remain constant in the assisted locomotion [Kao, 2010]. The present work investigates the adaptation of muscular forces in the assisted gait of healthy subjects to validate the mentioned solution.

Methods

Several methods have been proposed in the literature to overcome the load sharing problem, but all of them suffer from a high computational cost. The authors' method called 'Physiologically Static Optimization' [Alonso, 2011] gets, in a first step, the maximum force histories corresponding to the current lengths, assuming full activation. In a second step, those forces are scaled by the activation obtained in an optimization problem where weighted sum of muscular and orthosis power is minimized at each time step:

$$\begin{aligned} \text{Min } J(\mathbf{A}_m, \mathbf{A}_o) &= \omega_m \sum_{j=1}^N \left(-a_j f_{ce,j} v_{ce} \right)^2 + \omega_o \sum_{k=1}^3 \left(\frac{o_k T_{o,k}^*}{T_{o,k}^*} \right)^2 \\ \text{s.t. } \mathbf{R} \cdot (\mathbf{A}\mathbf{F}^*) &= \mathbf{T} \\ 0 &\leq a_j \leq 1 \\ -1 &\leq o_k \leq 1 \end{aligned} \quad (1)$$

The weight factors for both muscular and orthosis actuation were chosen so as to balance the two terms of Eq. 1. In this new work, to correct the selected weights, experimental measures of a healthy individual wearing the SCKAFO presented in [Font, 2011] (see Fig. 1) have been collected in the lab. To perform the control of this orthosis, a classic PI controller has been implemented, taking into account the patients muscle power and the tracking error of the knee motion.

Results

Net joint torques were calculated by means of the procedure explained in [Cuadrado, 2011] and, then, following the approach in [Alonso, 2011], the muscular forces and the distribution of the combined actuation orthosis-subject were obtained. Those results were compared with experimental measures in the laboratory (external assistance and EMG of muscular groups of interest) to: a) validate the hypothesis of invariant torque patterns; b) adjust the weight factors in the objective function; c) study the adaptation of such factors and muscle forces with orthosis usage.

Discussion

This work presents the analysis of the human-orthosis combined actuation in the assisted locomotion. Gait for several healthy subjects wearing the controlled SCKAFO have been acquired, walking at different speeds and with different training periods. Muscular adaptation and changes in the weights of the objective function have been investigated to understand the human adaptation to combined actuation.

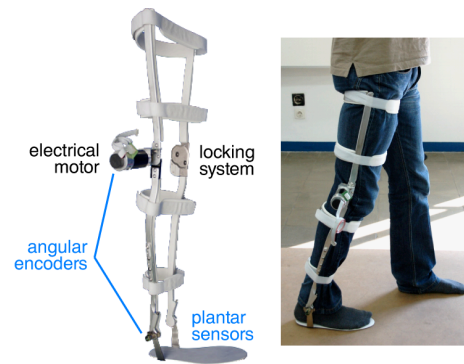


Figure 1: Proposed SCKAFO design [Font, 2011].

References

- Alonso *et al*, Multibody Syst Dyn, InPress, 2011.
- Cain *et al*, J Neuroengineering Rehabil, 4: 48 2007.
- Cuadrado *et al*, Procedia IUTAM, 2:26-34, 2011.
- Font-Llagunes *et al*, Procedia IUTAM, 2:68-81, 2011.
- Kao *et al*, J Biomechs, 43: 203-209, 2010.