TAILOR: Patient-Specific Hybrid Wearable Systems for Walking Rehabilitation

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***Abstract*— Personalization of robotic exoskeletons for walking assistance to the end user is still a challenge for this technology. The TAILOR project aims to create hybrid and modular robotic-neuroprosthetic wearable systems that can be adapted to an individual patient. For that, a User-Centered Design approach and predictive dynamic simulation tools are conceived to support the design of the hybrid assistive technology.**

I. INTRODUCTION

Walking rehabilitation is one of the principal objectives for people with neuromuscular impairments [1]. Robotic exoskeletons for gait rehabilitation, while promising tools, are not yet a sustainable and competitive product in the market. Our hypothesis is that these systems, all conceived as a generic solution for all kinds of patients, not adapting to the specific functional needs, as well as indtroducing artificial (device-related) impariments.

The TAILOR project aims at developing a new generation of modular lower limb wearable exoskeletons and neuroprostheses that enable delivering patient-specific robotic-assisted walking treatments in different neuromuscular impairments. TAILOR is not only focused on developing the associated technologies, but also investigating the criteria and procedures needed for personalizing them to the specific clinical and functional user requirements. The technology developed also has the capability of hybridation, where a robotic device and a set of neuroprostheses are combined as a single device for providing hybrid walking assistance. This personalization is also fundamented on musculoskeletal modelling and simulation, where computational patient-specific models are used to find hybrid-control strategies that optimize walking function.

II. TAILOR PROJECT METHODOLOGY

A. User-Centered Design and Unified Evaluation Framework

A key factor for customization of technology is to measure and assess user needs and expectations. Not only in functional terms but also user's expected outcomes (e.g., community or in-home ambulation), as well as expectations and emotional impact of the technology. The TAILOR project has deployed a comprehensive User-Centered Desing approach in which these and other important user-related factors are identified, assessed, and incorporated into the developed technology.

B. Modular Robotic and Neuroprosthetic Systems

The project develops a personal area network technology to establish modular systems of electrical stimulators to deliver current to diverse areas to be stimulated. This system con be configured and adapted to generate types of non-invasive muscle electrical stimulation to assist lower limb muscles during locomotion tasks. The modular electrical stimulation system consists of a hardware communication and control technology to configure a distributed electrical stimulation personal area network. Wireless electrical stimulation nodes (each with 4 parallel bipolar stimulation channels in the range 0-90mA) allow to vary the size of the network in a flexible and little obtrusive way, under a central control unit that serves also as the interface with the wearable robot for hybridization.

C. Musculoskeletal Modeling and Predictive Dynamic Simulation

Personalization of the hybrid robotic-neuroprosthetic systems are based on predictive dynamic simulations using computational human-device models. For this purpose, subject-specific musculoskeletal models of the selected patients, taking into account subject's functional status based on clinical exploration, are developed in OpenSim [2]. These models are complemented with a physical model of the robotic device and a phenomenological model of the muscle artificial activation from electrical stimulator parameters. The models are then used in an optimal control-based predictive simulation framework that allows to simulate optimal walking motions of the computational subject, given a hybrid control strategy of the robotic-neuroprosthetic system. These predictions will then be experimentally evaluated in the motion analysis laboratory with the real patient using the hybrid system with the same control strategy.

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