XoSoft - A Vision for a Soft Modular Lower Limb Exoskeleton

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Abstract XoSoft is an EU project that proposes the development of a modular soft lower-limb exoskeleton to assist people with mobility impairments. It aims to be user friendly and comfortable to wear, with a significant impact on the person's mobility and health, on their independence and quality of life. Being a modular system, it comprises of ankle, knee and hip elements, which can be used individually or combined and used unilaterally or bilaterally.

XoSoft follows a user centered design strategy achieved by involving primary, secondary and tertiary end users as participatory stakeholders in the design and

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development process. Preliminary findings of the interviews with the different users groups are presented in this paper.

Advanced textiles and smart materials are being developed to create sensing, variable stiffness joints and flexible tactile sensors. Control will be through biomimetics to identify the user's motion and intention and to determine and provide the appropriate level of assistance. Connected health connectivity and analysis will enable the wearer and their clinicians/therapist to review activity information. The concept will be tested extensively in the lab, and subject to trials in clinical settings and home environments.

1 Introduction

Many elderly and patient groups experience varying degrees of mobility impairment. Assistive devices play a pivotal role in their lives and impact on their ability to live independently and perform basic tasks of daily living. But many assistive aids do not encourage or support activation of legs, e.g. powered wheel chairs. The proportion of the world's elderly population is expected to increase significantly by 2050 [1]. Age-related decline in voluntary muscle strength results in important

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changes to body composition and function [2]. Remaining active and mobile during ageing is crucial to overall health and cognitive function [3]. Mobility assistance is also required by patients, such as stroke sufferers or patients with incomplete Spinal Cord Injuries (SCI). Globally circa 16 million people per year experience a stroke for the first time, of which 5 million experience varying degrees of mobility difficulty, which significantly impacts their ability to perform tasks of daily living [4]. Accidents are the most common cause of SCI lesions; of which about the 51 % are incomplete, i.e. the person is partially disabled [5]. Beside SCI caused by accidents, there are an in-creasing number of cases due to non-traumatic causes. A characteristic of the latter group is that patients are older and that the amount of incomplete SCI is even higher. Patients with an incomplete SCI do not suffer complete loss of sensory-motor function in the lower limbs but they may still require assistance to walk.

XoSoft is an EU project that is currently developing a soft lower-limb exoskeleton to assist people with mobility restrictions due a partial loss of sensory or motor function. Typically, the existing exoskeletons have a rigid structure that is heavy weight, bulky and is a risk for lesions due to excessive pressure to the skin. In contrast, XoSoft will have a flexible and adaptable structure. Its design will be lightweight due to the basic structure and the fact that assistance requires low power consumption (e.g. batteries). XoSoft is not intended to substitute complete loss of function like already existing exoskeletons, but rather assist the user in a tailored manner. XoSoft is a user centered design lower limb exoskeleton using smart soft robotics, biomimetic controlled actuation and connected health data feedback and interface.

2 User Centered Design

A core feature of XoSoft is that it follows a User Centered Design (UCD) approach [6]. UCD employs design ethnography and participatory stakeholder involvement as key drivers for the technology development to ensure user needs are at the forefront XoSoft's development. This approach also uses an iterative product design methodology which re-evaluates and improves the user appropriateness of the system at each stage. Three versions of XoSoft are identifiable based on the module and subsystem developed, and persons tested on:

1. **Alpha version:** This version is being designed using existing technologies and its main purpose is to use it as a test bed for the technologies and a mechanism to ensure the design process remains user centered.
2. **Beta version:** Based on the alpha prototype, we will replace and incorporate new technologies to the system. The different Beta versions of the system will be tested during laboratory setups. The last Beta version will include the full sensing and actuation system but with limited autonomous functionality. This version will be used in the clinical validation.

3. **Gamma version:** The final version of the Product Service System (PSS) will be fully autonomous as a person would use it (i.e. run on batteries and have an on-board computer) and it will be ready for the home trials.

3 User Groups

In this section we provide some preliminary results of the analysis of the XoSoft stakeholders and their needs, including demographics of the primary users (PU), identification of the secondary users (SU) and the commercial analysis of the tertiary users (TU).

We selected two distinct PU groups: neurological populations, specifically people with stroke and incomplete SCI, and older adults with mobility impairments. Apart from the assistive capabilities of the system, the PUs put special emphasis in the wearability and usability of the system, and in particular in the ability of using the system in their daily life, allowing then to use it under their normal clothes, and not impeding daily activities.

SUs are defined as persons or organisations directly in contact with a PU. Professional SUs include healthcare professionals from multidisciplinary backgrounds, such as physicians, nurses, physiotherapists, occupational therapists, speech and language therapists, and public health nurses, as well as professional care assistants, home help service providers and other support staff. Non-professional SUs may include spouses, family members, friends, neighbours, and community and/or voluntary organisations. The main focus of the SU is centered in the functionality of the system and the positive immediate outcomes for the patients, rather than in aesthetics as the PUs.

TUs are defined as bodies that have interests that are in some way affecting the potential for the device in question. They are often related to the framework that is in place on the regulatory side and/or to financial provisions for the devices that are supplied to patients or other users.

4 System Description

XoSoft exoskeleton comprises an ankle-foot-knee module which can be worn on one or on both sides and a hip module. All modules will be designed to be highly customizable and to be operated separately or in combination. XoSoft is meant to be easy to wear, comfortable, serviceable and compatible with the daily life of the users. These aspects will ensure a high acceptability by the users, being used not only in clinical environments but also at home and everyday life.

XoSoft uses non-traditional sensing and actuation systems based on smart materials and soft structures. Variable stiffness joints based on Electro-Rheological

Fluids (ERF) are being developed. Different solutions are being analyzed to develop flexible sensors to measure bending, stretching, force and pressure. In later stages, we will develop units fusing sensing and actuation capabilities based on the above technologies.

The system control uses a biomimetic approach, which requires the measurement and identification of the movement of the user. The system aims to inertial motion sensors to measure and identify gait patterns and other variables, such as kinematics, intention of turning, transitions, and instabilities. This information, used in conjunction with the biomimetic approach, determines the appropriate assistance and strategies.

The activity of the user will be monitored by providing connected online and offline feedback to the clinicians and users. The information will be segmented for easy analysis and understanding. The clinician or therapist can also adjust settings of the device remotely, for example to tune the device to provide more or less assistance.

The system should be suitable for use in home environments. Therefore, it must operate autonomously for long periods of time with low energy requirements (lower battery size and weight, less heat dissipation, etc.). To reach this objective we will optimize the power requirements for sensors, actuators and computing units (ultra-low power processors). For the most demanding actuation units we will use soft mechanical solutions for energy accumulation.

5 Conclusions

In this paper, we have presented the main characteristics of the soft exoskeleton, which will be developed in the XoSoft project, putting special emphasis in the user centered design process as well as preliminary findings from the analysis of the different user groups.

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