Towards Everyday Shared Control of Lower Limb Exoskeletons

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***Abstract*—We take a multi-faceted whole-system approach towards designing and implementing a neural interface for lower limb exoskeletons. This paper highlights some of the initial steps we have taken, from the development of shared control techniques to the characterization of the exoskeleton itself and the identification of brain signals that could be used in such an interface.**

I. Introduction

WEARABLE lower limb exoskeletons are designed to help people with paralysis walk, offering them more independence than conventional wheelchairs. Several such exoskeletons are now commercially available, but most require the user to balance themselves with crutches or some other external support. The Rex (robotic exoskeleton by Rex Bionics, NZ) offers full stability support so people who also have upper limb impairments can use it. However, the joystick interface and pre-set motions make it challenging to operate effectively in confined and cluttered environments. Several research groups are striving to achieve a more natural control of such exoskeletons by designing neural interfaces [1].

We believe that despite recent advances, current neural decoding resolutions and accuracies are not yet sufficient for everyday control of these exoskeletons outside laboratory environments. Therefore, the Aspire Create team takes a multi-faceted whole-system approach towards designing and implementing a shared control system that will work in tandem with the neural interface.

II. Shared Control

We are extrapolating our extensive experience in brain-controlled smart wheelchairs, such that the control authority will be shared between the user and the device [2]. The exoskeleton will therefore be able to: perceive its surroundings; use this information to interpret the user intent in this context; and then provide the user with an appropriate level of assistance in completing their desired task.

III. Lower Limb Exoskeletons

Our first steps towards implementing such a system, have been to characterize: the exoskeleton motion; the physical human-robot interactions; and the user's brain activity.

We first performed a gait analysis of the Rex using the Motek Medical Grail system at the Royal National Orthopaedic Hospital, Stanmore, UK. Not only did this allow us to compare the gait with a typical human gait and identify specific differences, such as the dorsi-/plantar-flexion [3], but it also enabled us to build a kinematic model that will be used by the shared controller.

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Next, we analyzed the profiles of the interaction forces between the lower limbs and the exoskeleton cuffs, which we found to differ significantly for each motion primitive [4]. This real-time information could be exploited both for safety and in the feedback control loop.

Our most recent preliminary electroencephalography (EEG) results show significant differences in the mu band power over the motor cortex, when able-bodied participants wanted to change their state (e.g. stand up, take a step, turn in place etc.) [5].

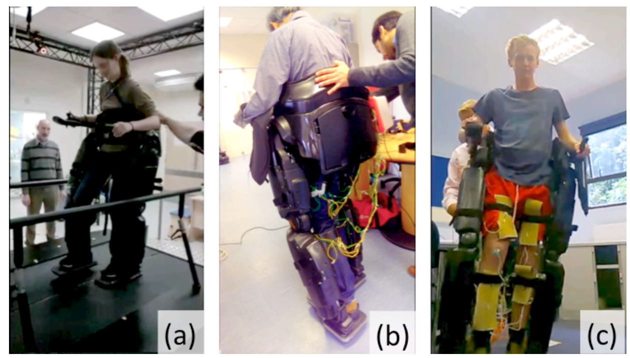

Fig. 1. (a) Gait analysis of the Rex using the Motek Medical Grail. (b) Measuring the physical human-exoskeleton interaction forces. (c) Simultaneously measuring interaction forces and muscular activity.

IV. Discussion and Future Work

Combining the results discussed here, we will implement a shared control system, such that the exoskeleton will be able to interpret the user's intent (from EEG)—given the context of the situation—and then generate appropriate sequences of movements to achieve the desired task safely.

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