Interfacing robotic exoskeletons with human somatosensory information for walking support

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I. Background

Robotic exoskeletons have large potentials for enhancing movement and preserving biological tissue integrity in a variety of scenarios: rehabilitation of paretic patients, prevention of work-related injuries or augmentation of human motor capacity. However, there are challenges hampering societal impact. One of them is the ability of assisting over large and diverse repertoires of walking conditions. Current research has focused on tests in controlled walking condition (a few speed/loading conditions). When multiple walking conditions were tested, state machines were primarily employed to switch between assistance patterns, limiting assistance to *a priori* chosen states [1]. This abstract discusses the computation of somatosensory information (*e.g.*, muscle/tendon kinematics and kinetics) from wearable sensors and the simultaneous voluntary myo-control of a bilateral ankle exoskeleton. We present a human-exoskeleton interface based on a person-specific neuromechanical myoelectric model [2]. Results show that the proposed approach enables the systematic reduction of muscle bio-electrical activity and resulting joint torques across a repertoire of "unseen" walking speeds and ground elevations, *i.e.*, not used for establishing the control model.

II. Methods and Results

The developed human-exoskeleton interface (HEI) is based on a real-time EMG-driven model previously introduced [2]. It uses a Hill-type muscle model fed by joint angle recorded by an IMU suit (knee and ankle sagittal angles) and EMG signals recorded via surface electrodes from muscles including the tibialis anterior, soleus and gastrocnemius medialis and lateralis. The HEI was connected to a bilateral ankle exoskeleton previously developed [3]. Model-based joint torque estimates were multiplied by a support ratio and sent to the exoskeleton low-level torque controller for providing mechanical assistance. Only a fraction of the biological torque is given as assistance (from 20% to 40%) as most subjects were naïve users. Experiments were performed on 4 healthy subjects (30±4 years, 177±6 cm, 71±6 Kg) and were approved by the Natural Sciences and Engineering Sciences Ethics committee of the University of Twente (reference number 2020.21). They consisted of one uninterrupted recording were each subject was instructed to walk across all conditions of speed and inclination, *i.e.*, 1.8 km/h, 0%; 1.8km/h, -5%; 1.8km/h, 12%; 2.8 km/h 0%, 2.8 km/h, -5%; 2.8 km/h 12%. Model personalization was done for each subject using the two tested speed at 0% elevation. Two exoskeleton conditions were tested: assisted and transparent mode (minimal impedance). Results (fig. 1) showed that muscular effort reduction (EMG and biological joint torque) between exoskeleton conditions was achieved over the full recording (Complete Experiment). Reduction was also always achieved for individual walking conditions. We also observed reductions in the transition between walking conditions (Fig. 1).

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III. Discussion and Conclusion

Results showed that the HEI could enable the exoskeleton to dynamically adapt to the mechanical demand of different unseen walking conditions and assist the subject accordingly. This was achieved with no need for defining a finite set of assistive modes (or machine states) *a priori*. Controlling exoskeletons based on estimated human somatosensory information may lead to myo-controllers that could flexibly operate in unstructured environments.

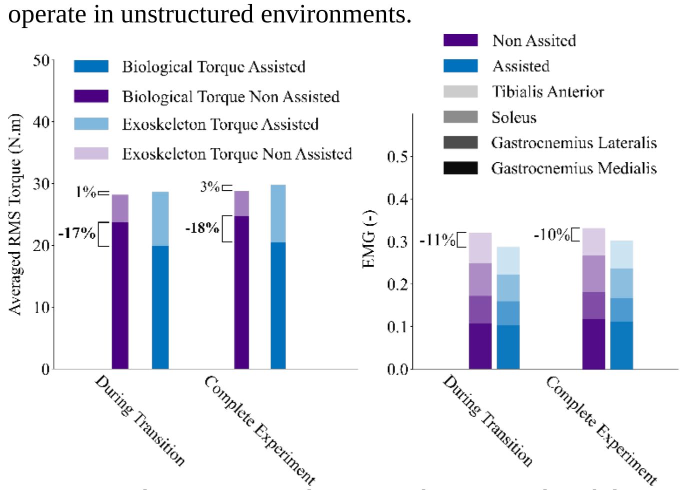

Figure 1: Reduction in EMG and joint torque between tested exoskeleton conditions.

References

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