NEUROMECHANICAL MODEL-BASED CLOSED-LOOP CONTROL OF LOCOMOTION VIA MUSCLE REFLEXES AND SYNERGIES

Huawei Wang* and Massimo Sartori

Biomechanical Engineering, Technical Medical Centre, University of Twente,
Postbus 217, 7500 AE, Enschede
The Netherlands

ABSTRACT

Current real-time neuromechanical model-based (NM) controllers for wearable robotics, such as exoskeletons and prostheses, often use electromyography sensors (EMGs) to detect users' motion intentions and then provide assistance that proportional to users' joint torques [1]. Even though, recent studies demonstrate that this control framework has the ability to adapt to variety locomotion conditions [1-2], neither placing surface EMGs nor implanting intramuscular EMGs is appreciated by both patients and healthy users. Moreover, the more sensors the more susceptible the system is to noise and movement artifacts. Computational models based on the concepts of muscle reflexes and synergies have been studied via both experiments and avatar-based simulations [3-4], showing that they can explain complex locomotion, for instance walking on uneven terrains, speed up/slow down, with up/down slopes, and turnings. Our work focuses on modelling the reflex and synergy controls in human locomotion and using them to close the loop within NM models so that EMGs will no longer be needed. In the first stage of our study, we answer the question about whether a common structure of reflex and synergy control models can be directly identified from walking data. To answer it, kinetic and muscle activation data of 5 healthy adults at 4 walking speeds (0.9, 1.8, 2.7, 3.6km/h) were collected. Models of muscle reflexes and synergies were identified from the dataset, starting from a fully connected state-feedback structure. This was done through trajectory optimization with the direct collocation method [5]. To our knowledge, the structures of reflex control models are normally defined manually, and the reflex gains are mostly optimized based on the simulations of avatars. This study enables for first time to identify both the structure of reflex control and its reflex gains directly from human walking data. In addition, combining reflex and synergy together to explain locomotion data have not been examined yet. This first stage study will also provide the computational cost information of such identifications, which can be used as reference for the next study stage where an online calibration tool of muscle reflex and synergy controls will be developed.

REFERENCE

[1]. Durandau, Guillaume, et al. "Voluntary control of wearable robotic exoskeletons by patients with paresis via neuromechanical modeling." *Journal of neuroengineering and rehabilitation* 16.1 (2019): 91.
[2]. Durandau, Guillaume, Dario Farina, and Massimo Sartori. "Robust real-time musculoskeletal modeling driven by electromyograms." *IEEE transactions on biomedical engineering* 65.3 (2017): 556-564.
[3]. Song, Seungmoon, and Hartmut Geyer. "A neural circuitry that emphasizes spinal feedback generates diverse behaviours of human locomotion." *The Journal of physiology* 593.16 (2015): 3493-3511.
[4]. Sartori, Massimo, et al. "A musculoskeletal model of human locomotion driven by a low dimensional set of impulsive excitation primitives." *Frontiers in computational neuroscience* 7 (2013): 79.
[5]. Von Stryk, Oskar. "Numerical solution of optimal control problems by direct collocation." *Optimal control*. Birkhäuser Basel, 1993. 129-143.

ACKNOWLEDGMENT:

This work is supported by the EU Sophia project with grant agreement No. 871237.