REAL-TIME NEUROMUSCULOSKELETAL MODELING TO ESTIMATE MUSCLE EXCITATIONS AND JOINT MOMENTS AT DIFFERENT WALKING SPEEDS*: A PILOT STUDY*

INTRODUCTION

Powered prosthetic legs are promising solutions to assist amputees locomotion in a large variety of conditions. However, passive devices are still the most common commercial solution. To fully benefit from the active device, the user has to rely on the dynamic control of it and, on its visual observations or incidental signals, to walk in a natural and safe manner. The absence of communication from the user to the prosthetic that can translate body states into control commands results in the adoption of non-natural compensatory movements [1].
An alternative solution to commercial finite state machines is given by musculoskeletal models driven by electromyographic signals (EMGs) that mimic the dynamics and motor control strategies in humans.
However, EMGs are not always available as sometimes muscles are removed. Instead, our control system includes a model to mimic the role of the central nervous system in giving movement commands in real-time. It may improve user-device interaction providing an intuitive and robust system.

METHODS

Considering the inherent redundant nature of the human neuromuscular system, it is hypothesized that the nervous system organises motor control by activating fixed groups of muscles as individual units, or muscle synergies.
In [2], a model that predicts the activity of leg muscles as a linear combination of four basic patterns for different walking speeds and elevations, was developed.
A real-time model of synergies was implemented from the aforementioned to predict joint moments using a real-time neuromusculoskeletal model, which takes muscle excitations data from EMGs to compute muscle-tendon units (MTU) forces and joint moments [3].
EMGs data are substituted from the model: in order to compute muscle excitations, at each timestep inputs are computed from the estimated gait phase, from ground reaction forces, and walking conditions informations (speed and elevation).
The joint kinematics is also required to compute muscle-tendon kinematics; combining these with the muscle excitations, joint torques can be estimated.

The validation of the neural model in real-time was done by comparing with joint moments estimated from inverse dynamics.
The experiments consisted of one healthy subject walking on a treadmill at different speeds (3 km/h ,4 km/h, 5 km/h). Inertial Motion Capture system, markers and Force plates were used to capture joint angles and moments.

RESULTS

The differences in the ankle torques for one leg were analysed computing the root mean square error (RMSE) and correlation factor. See complementary figure and table.

DISCUSSION

Our preliminary results showed good correlation and low error between torque estimated from the synergies and the gold standard inverse dynamics. This outcome confirms that synergy-driven musculoskeletal model can be a good alternative for computing joint torques with a reduced set of sensors.

REFERENCES

[1] Tucker *et al.*,JNE, 2015

[2] Gonzalez-Vargaset al.,” *Front. Comput. Neurosci.*, 2015

[3] Durandau et al., TBME, 2018

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