CMBBE 2024
19th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering
30 July - 1 August 2024, Vancouver, Canada

MINIMIZATION OF MUSCLE FATIGUE INDUCED BY FUNCTIONAL ELECTRICAL STIMULATION: A PREDICTIVE SIMULATION

Kevin Co (1), Pierre Puchaud (1), Florent Moissenet (2), Mickaël Begon (1)

1. Université de Montréal, Montreal (Qc) Canada. 2. Biomechanics and Kinesiology laboratories, Geneva University Hospitals and University of Geneva, Geneva, Switzerland

1. Introduction

Functional electrical stimulation (FES) is an efficient rehabilitation technique in patients with neurologic disorders. But it suffers from major flaws: 1) the rapid muscle fatigue onset due to fiber type-II overstimulation and 2) the stimulations' onset-offsets are suboptimal. Our objective was to design an optimal control method to optimize FES parameters to mitigate these flaws.

2. Materials and Methods

We have been developing CocoFest, an open-source Python package [1], to optimally control a musculoskeletal model driven by FES. In this study, the model included the biceps brachii (long and short heads), triceps brachii (long, lateral, and medial heads), and the brachialis to actuate shoulder and elbow in flexion/extension.

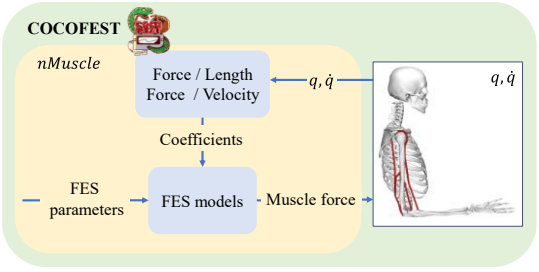

Figure 1: Forward dynamics model driven by FES.

Muscle force and fatigue were estimated using FES models [2] as functions of FES parameters (pulse durations). Muscle parameters were derived from a previous study [2]. For each muscle, the force scaling factor slope (αA, ms^{-2}) was proportionally modified regarding the literature on fiber type composition to simulate different muscle fatigue onset [3]. The same goes for the force scaling factor (A, unitless) regarding the physiological cross-section area. To reduce muscle fatigue, two cost functions were compared: (1) the minimization of muscle forces and (2) the minimization of overall muscle fatigue represented by the force scaling factor decrease. For this experiment, each pulse duration was optimized. The simulated movement was a reaching task, starting (0 s) and ending (1.5 s) with the arm at the vertical and reaching a distant point (40 cm) horizontally to shoulder joint (1 s).

3. Results

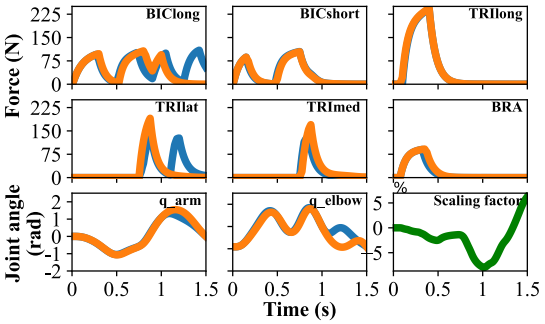

Figure 2: Muscle forces for a reaching task, minimizing muscle forces strategy (blue) or minimizing overall muscle fatigue (orange). Last subfigure represents the fatigue minimization gain percentage (green) between (blue) and (orange).

For this simulation, the muscle fatigue represented by the force scaling factor was better conserved at the movement's end by 6.25 % with the minimize muscle fatigue cost function.

4. Discussion and Conclusion

Present results show that muscle fatigue models can be relevant to optimally minimize muscle fatigue. The proposed package CocoFest can optimize FES parameters for various models and movement constraints.

5. References

[1] CocoFest: DOI:10.5281/zenodo.10672335
[2] Ding, J. et al., Muscle Nerve, 214-222 (2007).
[3] Dahmane, R. et al., J. Biomech., 2451-2459. (2005)