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An Adaptive Feedforward Control Structure for Functional Electrical Stimulation based Joint Position Control

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ABSTRACT *(USE STYLE: HEADING 1)*

Every year, between 250,000 and 500,000 people suffer from Spinal Cord Injury (SCI) around the world. Functional electrical stimulation (FES) is one of the assistive approaches that is developed to facilitate motor function movement. Usually researchers employ the FES to enforce the muscular system of SCI individuals and enable them to move. Accordingly, several methods have been presented to control the stimulation signals applied by the FES devices. However, due to the complexity of the human neuromuscular system and its time-varying nature, yielding an effective and practical control approach is still a challenge.

The surface FES device cannot efficiently apply the stimulation signal to a specific target muscle. A high portion of the applied current is thus waisted by leaking to unwanted muscle near to the stimulation site. Consequently, more electrical energy is needed to yield a desired level of torque, which leads to early muscular fatigue and rapid changes of muscle dynamics. This fact manifests the importance of having an agile and adaptable control strategy for FES system.

In this work, we present a new adaptive control strategy with a feedforward adaptive term in parallel structure with a PID controller. PID controller guarantees the stability of the closed-loop system in the course of adaptation, while the adaptive term is learning the optimal policy. The adaptive term optimizes the FES signal based on real-time (instantaneous) feedback from tracking-error. As a result of that, whenever fatigue or any other type of uncertainties alter the dynamics of the muscle-joint system, that change will be detected, and the adaptation rule will be triggered to update the feedforward controller accordingly.

The adaptation performance is analyzed in a simulation on a 2-DOF model with four Hill-type muscles, resemble a swing leg in the sagittal plane with a total length of 1m and a total weight of 12 Kg. In this simulation, the goal was to move the swing leg on an oval trajectory (rx = 0.3m and ry = 0.1m centered at (0,-0.8)m) with the frequency of 4 rad/s. PID parameters are set as P = 100, I = 1, and D=10 and the feedforward adaptive controller learns the optimal policy using five periodic sinusoidal bases. The adaptation converges to the optimal policy in 60 seconds. The adaptation minimizes the relative RMS error from 0.2% (without adaptation) to 0.05% at the end of the adaptation. The results indicate the effectiveness of this control approach and our next step is to experiment it on the healthy subjects.