POLITECNICO DI TORINO

Master's Degree in Biomedical Engineering

Master's Degree Thesis

The Impact of FES on Event-driven sEMG Information: A Preliminary Investigation

Supervisors

Prof. Danilo DEMARCHI

Ph.D. Fabio ROSSI

M.Sc. Andrea MONGARDI

Candidate

Pamela RUTA

March 2023

Abstract

The inability to move voluntarily can seriously affect a person's independence and quality of life. Stroke and Spinal Cord Injury (SCI) are the two most common causes of paralysis, affecting thousands of people worldwide. Significant efforts have been made to mitigate the effects of paralysis. Voluntary movement rehabilitation has been enriched in recent years by continuously incorporating new neurophysiological knowledge about the mechanisms underlying motor function recovery. One central concept that has significantly improved neurorehabilitation is neuroplasticity, which is the ability of the central nervous system to reorganize itself during the acquisition, retention, and consolidation of motor skills. Functional Electric Stimulation (FES) treatment techniques aid motor recovery by delivering electrical current pulses to patients through non-invasive electrodes using highly specialized equipment. This type of neurostimulation generates coordinated muscle contractions that mimic muscle functionality and provide patients with exercise benefits. An event-based system was previously designed to control FES in real-time. The system allowed accurate replication of the movement performed by a therapist on a patient subject by automatically modulating the intensity of electrical stimulation. For this purpose, a wearable device based on the Average Threshold Crossing (ATC) technique was used to extract meaningful information from the surface ElectroMyoGraphic (sEMG) signal taken by the therapist. Stimulation patterns are consequently derived and transmitted to the patient in real-time via surface electrodes but without providing feedback from the patient to the system. The goal of this thesis project represents a step toward optimizing the previously realized system. It aims to insert a feedback from the stimulated muscle as a further input to modulate the FES parameters and make the therapy more appropriate and efficient. The idea is to acquire the Threshold Crossing (TC) signal and evaluate muscle activation during the stimulation session in different circumstances. An experimental protocol was established and tested on the thesis candidate to evaluate the behavior of the Biceps Brachii and Quadriceps Femoris muscles. Muscle activation was recorded in the cases of pure stimulation and in combination with voluntary activity in isometric conditions. While the main FES parameters were varied, the voluntary contribution was standardized by measuring the Maximum Voluntary Contraction (MVC), of which the percentages of 20%, 50% and 80% were selected. From these tests, five clusters were defined depending on the total charge injected by the stimulation pattern. Based on them, two main features, i.e., the events width and the number of events, are extracted from the TC signals to characterize the muscular activation. Subsequently, five participants were selected to perform a subset of appropriate stimulation pattern combinations to compare the results with the preliminary tests.

The results showed an increase in both TC-extracted features, contrarily to the preliminary tests in which an increase up to the intermediate cluster and a decrease in higher clusters was shown. To investigate anomalous behaviors, a study was conducted on the sEMG signal by observing the effect of stimulation on TC signals. It emerged that at high levels of injected charge, a stimulation artifact overlaps the evoked muscle response (M-wave), preventing the assessment of voluntary muscle activity. Because of the contamination of the sEMG signal due to the stimulation artifacts, it was discovered that the TC signal extraction technique does not always produce the expected results. A new threshold calibration methodology was tested via software to overcome this limitation. This new methodology consists of calibrating the threshold during stimulation so as to adapt the ATC technique to the morphological changes of the sEMG under stimulation conditions. New tests were performed to validate this technique. Accordingly, with an MVC level of 40%, stimulus amplitudes less than 12 mA, and frequencies from 10 to 50 Hz, the technique shows promising in distinguishing the contribution of voluntary activation.