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Live Demonstration: A Real-Time Bio-Mimetic System for Multichannel FES Control

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***Abstract*—This demonstration presents a bio-mimetic system for the real-time multichannel control of Functional Electrical Stimulation (FES). The intensities of the FES profiles are directly mapped by processing surface ElectroMyoGraphic (sEMG) signals detected from synergistic muscles, thus achieving a user-comfortable stimulation that follows the monitored physiological patterns. Furthermore, a user-dedicated calibration routine and multiple versatile operating configurations allow the system to be integrated into standard rehabilitation protocols to enhance the restoration of motor functionalities.**

***Index Terms*—Activities of Daily Living, Electromyography, Functional Electrical Stimulation, Rehabilitation Engineering**

I. Overview

Spinal cord injury, stroke, and multiple sclerosis neurological disorders are still among the leading causes that gravely compromise the quality of life for people suffering them. Depending on the severity of the neuromuscular damage, some motor functions could be (partially) restored by participating in rehabilitation sessions. The application of Functional Electrical Stimulation (FES) therapy to skeletal muscles has been demonstrated to induce several benefits, e.g., promoting neuro-plasticity, maintaining muscular body mass, and preserving tissue circulation. Recent studies [1] explored how the combination of the active modulation of the FES parameters, defined by processing the surface ElectroMyoGraphic (sEMG) information, and the synergistic stimulation of coordinated muscle groups further enhances functional recovery.

In this demonstration[1], we present the latest implementation of our sEMG-controlled FES system, which correlates voluntary muscle activity profiles with computed bio-mimetic FES patterns. Starting from the system architecture reported in [2], here we replace the sensing units with our new custom wearable acquisition devices [3]. Furthermore, additional processing modules have been implemented to achieve independent and synergistic muscle stimulation simultaneously, thus allowing the operator to perform and control the evolution of coordinated movements easily.

Fig. 1 represents one of the proposed operating scenarios, which involves two subjects, the therapist (left) and the patient (right), during the execution of a typical daily-life action, e.g., drinking from a bottle. The subjects are supposed to be seated one in front of the other to follow the entire motion visually. The fast setup requires placing the acquisition devices and the stimulation electrodes above the desired muscle bellies. After the system initialization (e.g., pairing between acquisition and stimulation channels), a calibration routine balances the therapist's muscular activity with the FES pulse intensity suitable to elicit an adequate muscle response in the patient. Then, the FES session can start: the exercise performed by the therapist is induced in the patient, who, as instructed during the calibration phase, would try to complete the movement to the best of her/his physical condition.

[1]A preview is available at https://youtu.be/9-rx6uZ4w_I.

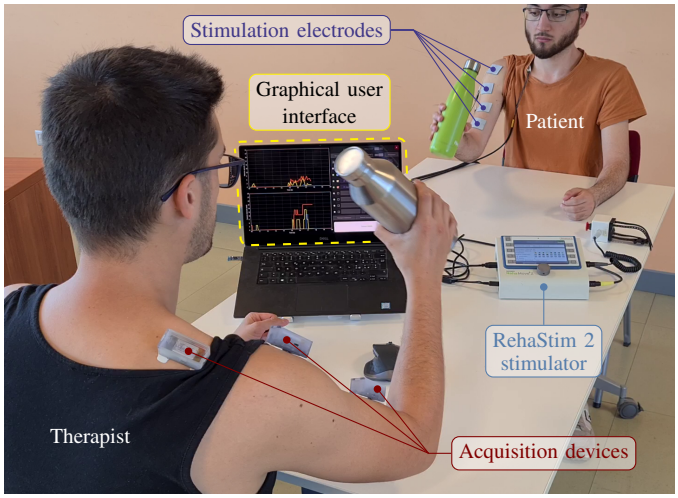

Fig. 1. Representative setup for the therapist-patient configuration.

II. Visitors Experience

Visitors can view and eventually participate (limited to the therapist role for medical-security reasons) to a simulated rehabilitative session, experimenting the following system functionalities:

- Bio-mimetic FES profiles generation;
- Therapist-patient real-time movements replication;
- Self-controlled FES patterns modulation;
- Pre-computed stimulation sequences.

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