Sensor and Control Concepts for Neuro-Interface Prosthetic Devices

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I. Introduction

The restoration of complex, physiological movements, especially for the upper limbs, by means of Functional Electrical Stimulation (FES) in neuro-interface prosthetic devices is still limited by the almost unpredictable, nonlinear and time-varying nature of artificial muscle activation [1]. In the past, an increased effort in personalized modeling of the musculoskeletal model was expended in order to tackle this problem [2]. However, such procedures are usually time-consuming and therefore not practicable in daily life.

II. Methods

This lecture discusses new control concepts for movement control that use cascaded control schemes based on FES-evoked EMG and/or acceleration recordings [3-8]. Both allow a rapid assessment of FES-induced muscle contraction. A fast inner control loop based on this information directly controls the amount of contraction (torque/force). Fig. 1 illustrates the control system structure when using EMG measurements to estimate the level of muscle contraction. The FES evoked EMG (M-wave) is shown in Fig. 2 for one stimulation period. The EMG-measurement electrodes are placed in between the pair of stimulation electrodes. The amount of muscle contraction (recruitment level λ) is estimated from the EMG for the indicated time windows by analyzing signal amplitude and intensity.

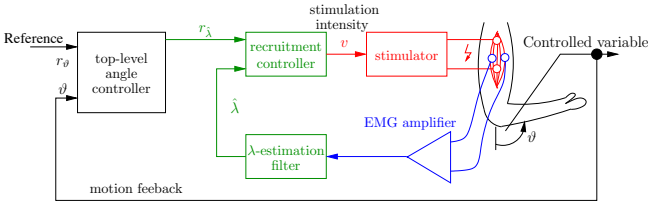

Figure 1. Cascaded control system with measurement of the evoked EMG exemplarily applied to the biceps.

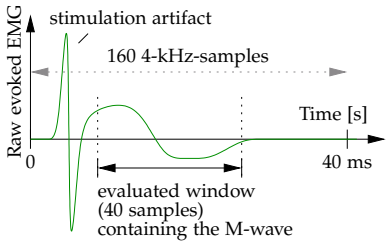

Figure 2. Stimulation artifact and M-wave occurring after a stimulation pulse.

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III. Results

The feasibility of the proposed control methods has been demonstrated for the control of the elbow-joint angle [3-5], the shoulder horizontal rotation [7,8] and for control of a drop foot stimulator [6]. For antagonistic muscle pairs, the vaguely known input nonlinearity (dead-zone) could be linearized by this approach without the need of extended system identification [4,7,8]. Even a precise control of muscle co-contractions can be achieved and exploited for movement generation when evoked EMG measurements are used for feedback control [7]. Fig. 3 shows exemplary the achieved performance of the shoulder horizontal rotation control by means of FES. The bold solid line represents the reference. The desired nominal system output and the measured one are shown as dash and thin solid line, respectively.

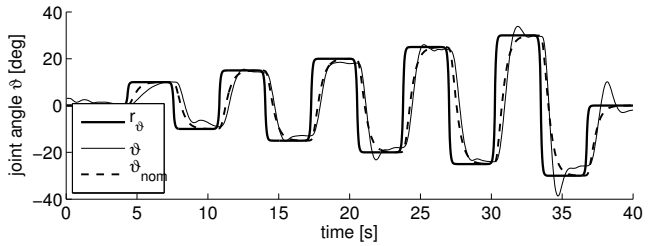

Figure 3. Results of the FES control for shoulder horizontal rotation using underlying λ–controlled antagonistic muscles [7].

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