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PORTABLE MULTI-CHANNEL ACQUISITION SYSTEM FOR INTRINSICALLY SAFE, HIGH RESOLUTION, REAL TIME PROCESSING HD-SEMG

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SUMMARY

Advanced surface EMG measurement techniques (High Density EMG) require a new tool to detect EMG potential on large skin surface by means of a large number of electrodes (up to 512). A new modular solution for a multi-channel acquisition system for both laboratory and field applications is presented. A multi-channel (64-424) prototype amplifier was designed and built (see specification in Table 1) and used to study the biceps brachii muscle in dynamic conditions.

Table 1: Prototype characteristics.

Parameter	Description	Value	Unit
N_{CH}	Number of channels	64	
G	Amplifier Gain	192	V/V
BW	Analog Bandwidth	[20 –1000]	Hz
v_n^{RTI}	Total RMS Voltage noise within EMG bandwidth (Referred-to-Input)	1.5	μV_{RMS}
f_s	Programmable Sampling Frequency Range per channel	[2 – 9.75]	ksps
N_{bit}	Number of bits on A/D conversion	24	bit
ΔV_{EMG}	EMG Voltage Resolution	<500	nV

The system was used to study time course of the innervation zone (IZ) of both heads of the biceps brachii during repeated concentric and eccentric contractions as well as the speed of shortening / lengthening of the two heads.

INTRODUCTION

The proposed wearable device (under patenting) consists of a modular solution, dynamically configurable, equipped with an optical fiber interface and powered by battery.

The basic system setup options are: a) Configurable number of channels by selecting the number of boards to be assembled; b) Recording features (sampling frequency, digitizing resolution); c) Two sEMG detection modes Monopolar or Single Differential Mode. Electrical test and real sEMG measurements were carried out to validate the system specifications reported on Table 1. Specifically the EMG channels output noise floor, filter bandwidth, voltage gain accuracy, effective number of bit resolution (ENOB), CMRR, and mismatches among channels were evaluated. A PC-based application tool was developed to monitor the distribution of spectral variables on line. A sixty-four channels prototype was assembled and fully tested to validate the expected performances. The prototype was optimized for portability, for maximization of data throughput for data storage, and minimization of power consumption. An on field testing was carried out to validate the acquisition system performances during a real EMG activity recording session. Specifically, an athlete was monitored during biceps curl exercise to detect EMG activity from biceps brachii's heads. The aim of the experiment was to evaluate the performances of the proposed wearable equipment during dynamic conditions. The HD-sEMG measurements enabled to continuously monitor, record and observe targeted muscles during dynamic tasks.

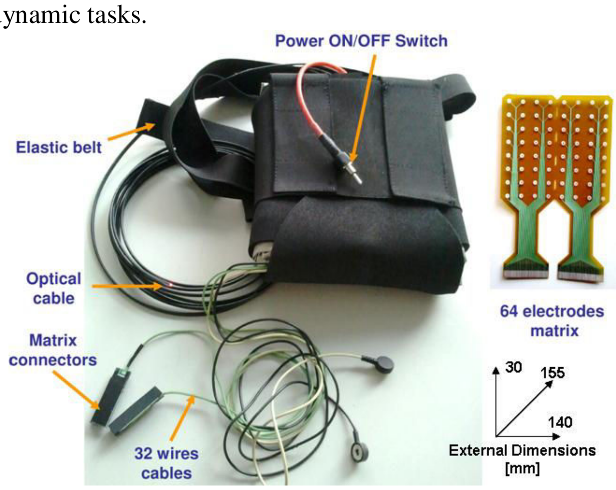

Figure 1: Overview of full wearable multi-channel acquisition system for HD-sEMG recording. Flexible electrodes matrix, lightweight cables and connectors were developed by LISiN staff.

METHODS

A flexible, kapton-based electrode matrix (70mm x 70mm) with 10mm of inter-electrode distance was used to detect EMG signals. Two lightweight, 32 pins, silicon cables (7g of weight with 1mm diameter) were used to connect the 64 electrodes matrix to the acquisition system (see Fig. 1). The training session consists of a dynamic contraction task based on weight lifting. Four consecutive repetitions were recorded to investigate the capability of the system to provide information about muscle's behavior. During each cycle the athlete produced a concentric and an eccentric contraction (flexion angle range of 90°). The High Density EMG technique (HD-EMG) was used to track the innervation zones (IZ) displacement of the two heads (IZ_A for short head, IZ_B for long head) during muscle shortening/lengthening. The 2D map visualization of RMS amplitudes (Fig. 2) and time plot of RMS envelopes (Fig. 3) were used to investigate the EMG activity. The raw samples were detected in monopolar mode (MP). The software tool displayed on-line the corresponding RMS of single differential signal (SD) 2D maps.

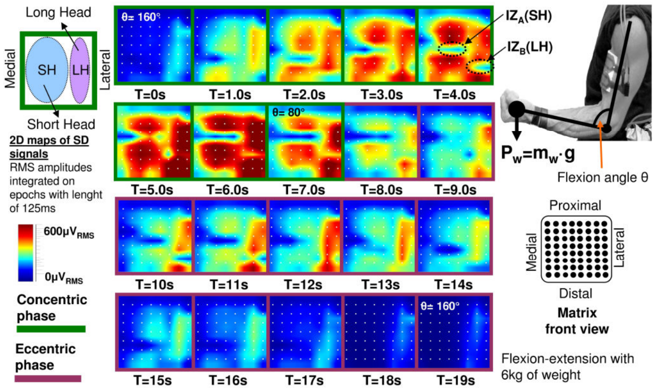

Figure 2: Sequence of single 2D Maps of RMS amplitude of SD signals during one flexion/extension cycle. The RMS amplitudes were computed on 125ms epochs. The epoch length was selected taking into account the speed of the moving limb from the exercise videoclip (≈4.2°/s). The biceps brachii activity was frozen every second to observe changes of muscle activity during the execution of the task. Observe how both heads are used to produce flexion (concentric phase) and mostly the lateral head (LH) is used to control extension (eccentric phase).

RESULTS AND DISCUSSION

The sliding of IZ under the electrodes could be described by means of two parameters: a) The lowest RMS value reached during the falling phase according to [1]; b) The time interval (number of epochs), spent to hit the trough and rise up to the common trend. For example, the speed of IZ_A (short head) or speed of muscle lengthening or shortening could be evaluated according to these two parameters which affect the shape of the falling phase. Fig. 3 reports the EMG envelopes during one repetition. The observed amplitude falls are characterized by two typical profiles: a) V profile (high speed); b) U profile (low speed). The subject moved the forearm with high speed during concentric phase (V profile), and slow speed during eccentric phase (U profile).

CONCLUSIONS

The results reported in the previous section show the advantages of the wearable system. In particular, the wearability of the system, and the lightness of the cables and connectors made it possible to carry out EMG measurements even during dynamic conditions, minimizing the effects of motion artifacts and interference with movement.

Each of the minima of one of the curves on Figure 3 indicates the time when the IZ is just below a specific SD channel (that is a specific electrode pair) of the chosen column. Dividing the inter-electrode distance by the time interval separating adjacent minima provides an estimate of the instantaneous (linear) velocity of muscle shortening.

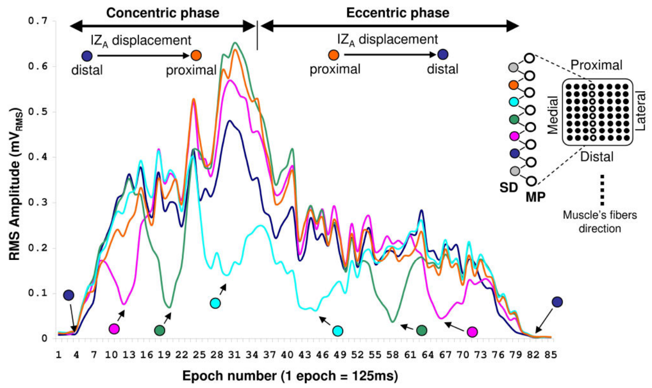

Figure 3: The single differential signals detected by channels on column 4 were processed to plot the time course of RMS amplitude. The RMS values were computed on epochs of 125ms during one repetition. Each curve corresponds to each SD channel according to color assignment. The electrodes are aligned to muscle fiber direction, and are ordered as shown on the legend on the right. The figure highlights a common trend identified by the overlapping behavior of the curves. The colored circles mark the events when one of the channels detects a minimum of RMS values. The event arises in correspondence of the passage of IZ_A underneath the channel with the same color of the affected curve. As described on the top of the figure, IZ_A moves from the distal portion of the muscle towards the proximal end during the concentric phase, and vice versa during the eccentric phase.

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