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EMG & EIMG measurement for Arm & Hand motions using custom made instrumentation based on Raspberry PI

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***Abstract*—Recording and processing physiological signal that give intrinsic characteristics information is one of scientific community needs. Electromyography (EMG) and Electrical Impedance Myography (EIMG) are both non-invasive approaches to measure and evaluate the muscle conditions and activity. Z-RPI device is a custom-made measurement device developed basically for ECG and ICG records. This paper presents the feasibility of acquiring surface EMG and EIMG signal of biceps and forearm muscle contractions using the Z-RPI device. The results obtained are acceptable, encouraging and converge to literature result. Thus, it shows that the Z-RPI device can be used for relatively several biomedical applications other than the ECG and ICG measurement. For supporting developers in research and engineering education.**

Keywords—Electromyiography, Eelctrical impedance myography , Rapsberry PI, Biomedical System, motions detection.

I. Introduction

Information issued from muscles are of interest in several domain especially sports with the aim of improving technical skills and, at the same time, athletic performance. Developing myoelectric prostheses that aim to help amputees to experience partial function of the absent limb is one of the important applications.

The most widely used method in the medical sports community or medical personnel in the field of muscle rehabilitation is Electromyography (EMG) measurement [1, 2]. It was the French Dubois-Reymond who in 1849 made the first recording of the EMG signal. The use of surface electrodes is the most common method for its collection, since it is non-invasive and can be conducted by non-physician staff, with minimal risk to the subject [3].

EMG signal have been used in several disciplines and Researches domain such as : biomechanics, neuromuscular disorders or sports and rehabilitation laboratories. In addition to engineering fields like instrumentations and signal processing, biomedicals and prosthetics control. The EMG can be a source of information about muscles health, motor control, neuromuscular physiology and many others [4]. Moreover, it is used as a control source for limbs prosthetics in order to comprehend and translate motor intent in bionic prosthesis [5].

One of the other methods that may offer a simple non-invasive approach to the evaluation of muscles condition is electrical impedance myography (EIMG). The first appearance of this measure was in 1950s and on skeletal muscle early in 1960s. The EIMG is easy to employ and is sensitive to muscle fiber size and muscle volume [6]. EIMG measure can be used to obtain information about muscle health and condition. For instance, it is used to observe muscle fatigue. Which is a symptom to diagnosis neuromuscular and neurological diseases [6], and in injury assessment [7]. Another lacking application is the measure of EIMG and its variation with muscle contraction and flexion. Most studies that cover EIMG measure are done with the muscle being relaxed [8, 9].

The scientific community needs open access and/or open hardware solutions for detecting, recording and processing physiological signal. And extract essential characteristics information for the deployment of novel applications based in biomedical sensing technologies, to educational and research development purposes.

The Z-RPI device is a custom-made measurement device that simultaneously records a 3-lead electrocardiography (ECG) and impedance-cardiography (ICG) signals, combining the following system-on-chip (SoC) solutions: the ADAS1000 and the AD5933 from Analog Devices with a Raspberry PI3 card. The regular configuration of the Z-RPI device uses 8 electrodes: 4 electrodes for measuring ICG, 3 electrodes for ECG; and 1 electrode for the RLD (right leg driven) circuitry, placed in the peripheral extremities (hand and leg) for the ECG [10].

We aim in this work to present the feasibility and the ability of surface EMG (sEMG) and EIMG signal measurement using the Z-RPI device for arm and hand motions detection.

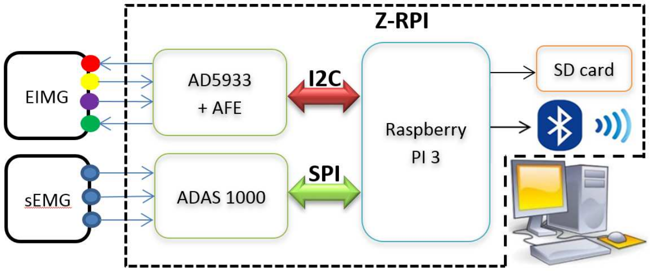

Fig.1: Description chart with the functional blocks.

II. METHOD

Fig.1 present the description chart diagram with the different functional blocks used in this work.

A. Experimental Measurement Setup

The experimental evaluation was performed at LINS Laboratory at the University of Sciences and Technology Houari Boumediene, Algeria, on a male healthy volunteer. The Z-RPI device was constructed for non-invasive acquisition, and the validation of biopotential and bioimpedance measurement have been performed many times [10,11].

The measurement of the sEMG signal were done using the SoC ADAS1000. And the EIMG were done with SoC AD5933+AFE, both signals are acquired for a duration of more than 60 seconds.

A series of experiment are done and divided as following:

- First, the arm is extended on a position in parallel to the body, after 10 seconds of measurement the volunteer makes 04 series of arm flexion and extension movements. After that, the volunteer waits for 10 seconds before pursues the new series of 07 arm flexion and extension movements (the movement is to bring the wrist closed and not tightened as close as possible to the shoulder). Secondly, another type of measurement is done, this time, the arm is in lengthened position. The volunteer makes a fast-bending flexion and extension movement of the arm. Thus, after ten seconds, the volunteer makes a slow bending flexion and extension movement of the arm. The goal is to see if the Z-RPI system is able to detect and provide an indication on the speed of performed motion. This experiment was done at a sample frequency of 340 Hz.
- Second, a test with only using the ADAS1000 at 2 kHz is done. This shows if we can get measurement of sEMG with altering normal and rapid arm movements.
- Third, the placement of the electrod is moved to the forearm, in order to perform 5 movements of the hand which are: wrist flexion and extension, ulnar wrist, closed hand rotation, open and close hand. All of those movements have been acquired at a sample frequency of 340 Hz.

The choice of those experiments was due to the encouraging results presented in the literature [3, 9]. Thus, to have a valuable base to compare the result of this actual work. Fig 2 shows the spots for the placement of the 3M repositionable Ag/AgCl gel electrodes used for performing the sEMG and EIMG recording for the different measurement test.

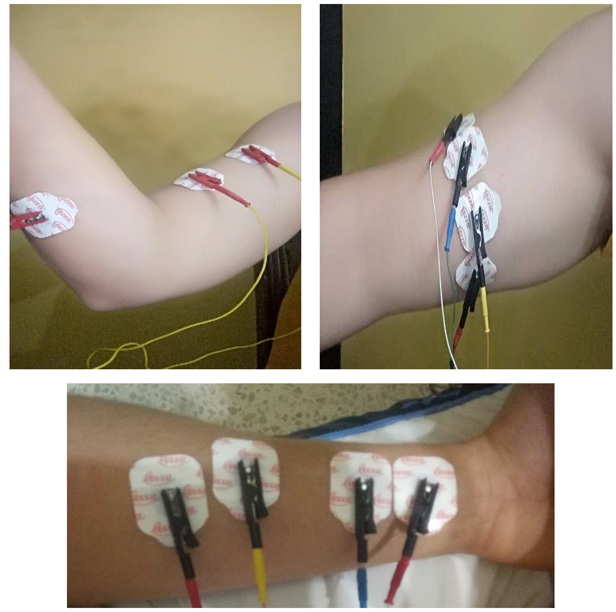

Fig. 2 Placement of electrodes for arm movement: sEMG (upper left), EIMG (upper right), and hand movement EIMG (down).

B. Data analysis and preprocessing

The recording was processed and analyzed off-line on the PC using a customized program running MATLAB. For the first and third application the sEMG and the EIMG were both lowpass filtered with a cut-off frequency of 3 Hz. For the second application of movement speed a bandpass filter was used with a cut-off frequency of 1-7 Hz, and for sEMG measurement a bandpass Butterworth filter of 20 to 500 Hz were applied.

C. Wirless communication

Several means to communicate with another system or PC are accessible for users with Raspberry PI3. In this work, Bluetooth was chosen to implement the wireless communications, with implementing a Bluetooth RFCOMM protocol to transmit the sEMG and EIMG samples acquired.

III. RESULTS

Fig. 3 present recording of sEMG and EIMG on the biceps brachial muscle during arm movement. Fig. 4 presents recording of sEMG for the same muscle for a fast and slow arm movement, and Fig. 5 present an example of 6 seconds of sEMG acquired with the ADAS1000 at 2 kHz.

Fig 6 to 9 shows the different waveforms acquired form EIMG measurement for electrodes configuration placed on the forearm and according to the different movement of the hand.

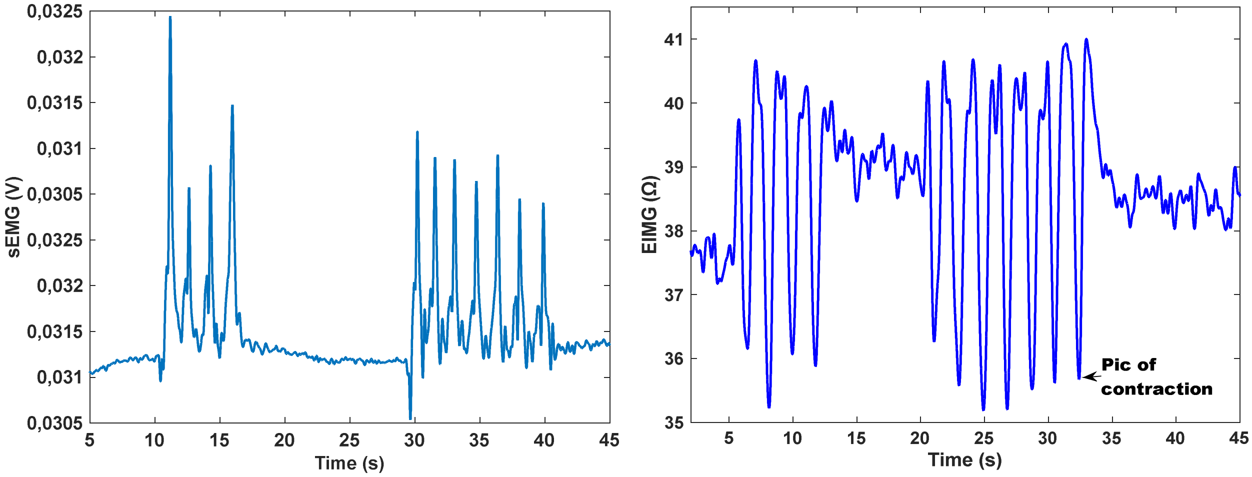

Fig. 3: Recording data during biceps muscle for arm movement, sEMG (left), EIMG (right).

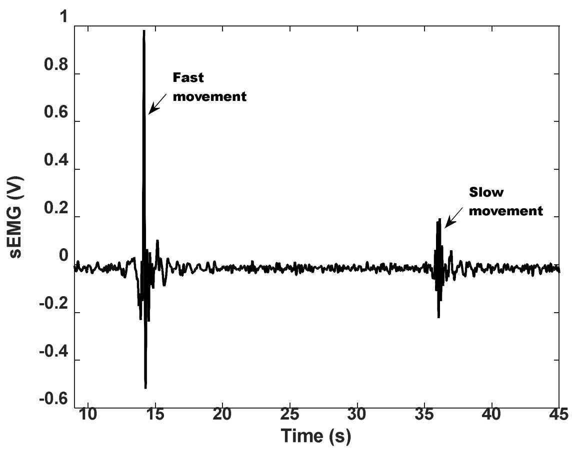

Fig. 4: sEMG fast and slow arm movement.

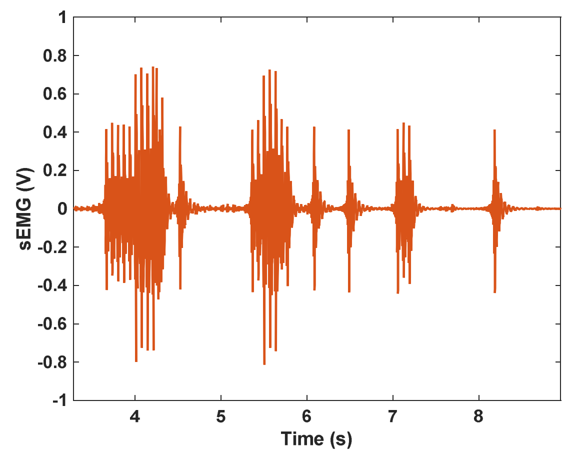

Fig. 5: sEMG measurement at 2 kHz.

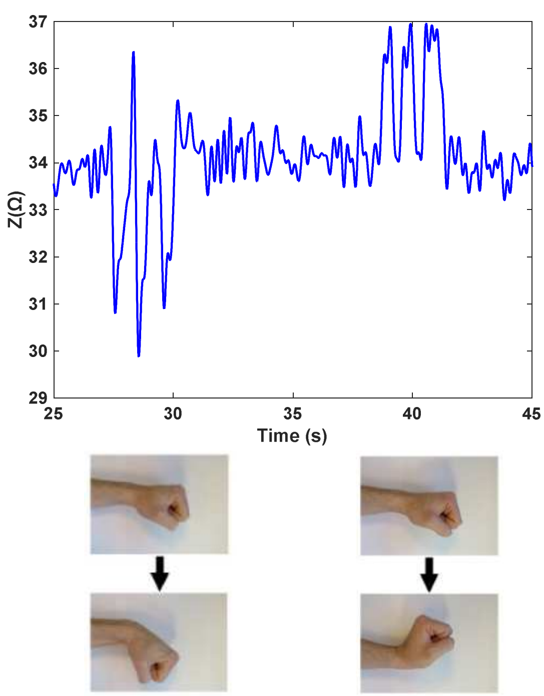

Fig. 6: 3 time flex and extension wrist.

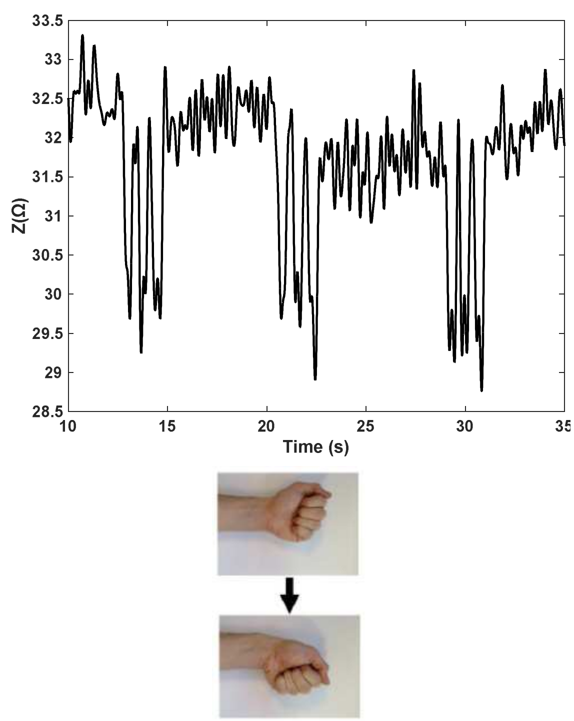

Fig. 7: 3*3 time ulnar wrist.

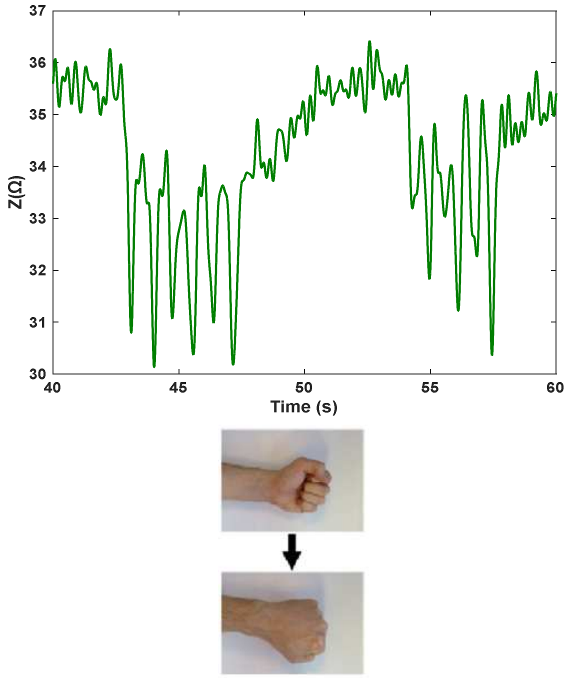

Fig.8: 3 time closed hand rotation.

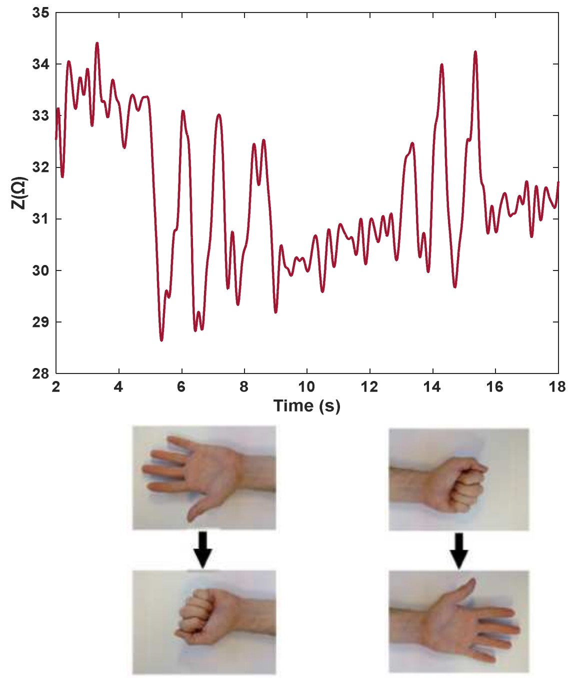

Fig. 9: 3 time open and close hand.

IV. Discussion

During the rest position the signal is constant and present no information. Nevertheless, Fig. 3 shows clear pics during biceps contraction, those later are directly correlated with the number of complete biceps brachii muscle contraction according to the experimental measurement setup.

The execution speed of the movement is also clear for the measurement of sEMG, this type of rapid arm movement generates a peak with high amplitude clearly noticeable, which could be an interesting indication for acquiring information in sports application.

The EIMG signal acquired from hand movement due to electrode placed at the forearm is clear, and noticeable pics could be easily detected, those result have similar behavior as presented in [9].

The result obtained do not need a high sampling frequency or specific complex filtering to get the signal envelope as it is commonly required for the EMG measurement [12].

Despite the fact that the ADAS1000 is primarily designed for ECG application. Based on the results, we can see that ADAS1000 can also work as an EMG analog front end as well.

V. Conclusion

The evaluation of the results shows that the Z-RPI device functions effectively when performing EIMG and sEMG measurement. Thus, clear signals have been obtained for both biceps and forearm muscle, during their contraction for the different movements.

The Z-RPI is an embedded system designed for simultaneous ECG and ICG measurement. However, this work has shown that, the Z-RPI can be used also for other biomedical applications developed for first steps research and/or engineering education in several field, within one single device.

More experiment and tests should be done on several volunteers, and data obtained from those experiment have to be comparing with reference data to evaluate the accuracy and the reliability of the system. However, measuring EIMG and sEMG using Z-RPI present perspective toward its potential use for clinical and medical applications.

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