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Position control module of myoelectric prostheses for people with upper limb loss at forearm level

C A Arenas¹, R E Monterroza², A J Marrugo² and L Rojas¹

¹Facultad de Diseño e Ingeniería, Fundación Tecnológica Antonio de Arévalo, Cartagena, Colombia.

²Escuela de Ingeniería de Sistemas, Universidad del Sinu seccional Cartagena, Cartagena, Colombia

carlos.arenas@tecnar.edu.co

Abstract. This project emerges as a solution to the problem present in the Colombian population with upper limb movement disability, related to access to prostheses that provide them with a better performance in their daily and work activities, thus offering them a better quality of life. The objective of this project will be to build prostheses with state-of-the-art technology at relatively lower costs than similar versions in other countries, as well as strategies for people with limited resources to access them easily.

The scope of the project is limited to the construction of a control module, that will be divided into two phases, the first phase covers the design of the EMG signal acquisition system; this will focus on the establishment of the design criteria necessary for the acquisition of the myoelectric signal, model for obtaining the characteristics of the EMGs signal in the time domain and, parameters for the identification of the movements. And a second phase, where the acquisition module is developed, for performing functional tests with EMGs signals in real time, in order to be able to calculate the percentage of error between the expected value and the real value.

1. Introduction

In Colombia, there are currently 413,269 people with disabilities that have alterations in the function or body structure related to the movement of the body, hands, arms or legs [1], of which at least 29,727 require upper limb prostheses. Despite the aforementioned and the advantages shown by myoelectric prosthetics to restore functionality to the subjects, this type of prosthesis has not yet been developed commercially in Colombia, this situation extends to the rest of Latin America, with the exception of Argentina where there are advances in such matter. Now, the process of manufacturing low cost prosthetics involves the use of durable and low cost materials, as well as the development of control models that can be implemented in open hardware systems of sufficient performance to obtain good results, which implies a challenge of fairly large design, considering that the processing of the EMGs signal requires a large calculation capacity that directly affects the performance of the hardware, and therefore the manufacturing costs. In addition to this, patients, follows-up is often complicated, since when faults occur in the equipment, vital information cannot be accessed at that precise moment, where variables such as energy consumption, movement and time of use can be related. These variables are important during the monitoring process to detect early failures and improve the models used.



2. Methodology

2.1. Muscles selection

For the signal EMGs acquisition, two antagonist muscles of the forearm were selected, considering that the level of amputation or loss of the forearm is in the distal third, these muscles were: the long supinator and pronator round. Figure 1 shows both muscles and how they intervene in the movements of supination and pronation of the forearm.

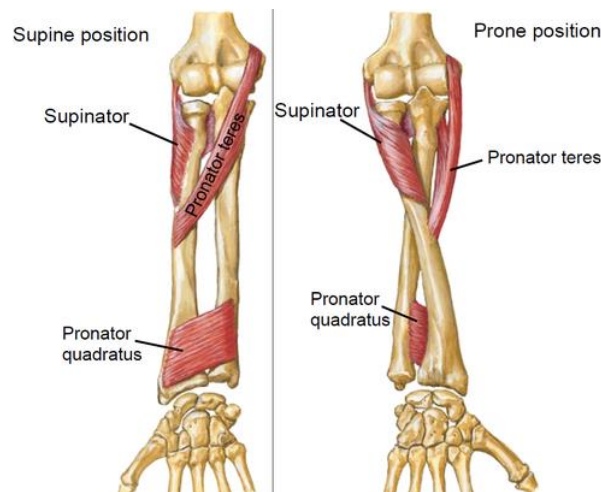


Figure 1. Supine position and Prone position

Taking into account that the best location to record EMG signal is in the central area of each muscle. It should be noted that we worked with healthy muscles in people who were not amputated [2].

Figure 2 shows the electrodes located in the muscles, where the blue electrode corresponds to the main entrance of the instrumentation amplifier, the red electrode to the secondary entrance and the black electrode to the reference.

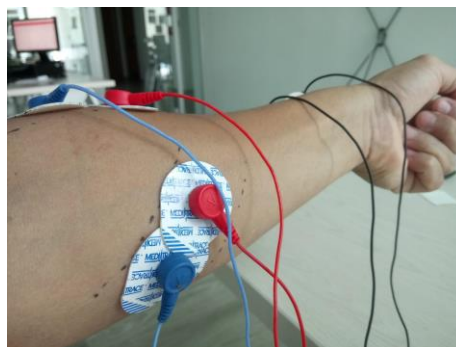


Figure 2. Location of the electrodes (two channels)

2.2. Signal Acquisition

For the acquisition of the signal, two Olimex Ekg-Emg modules were used, connected to an Arduino Uno module. Due to each module (shield) has a channel. See figure 3.

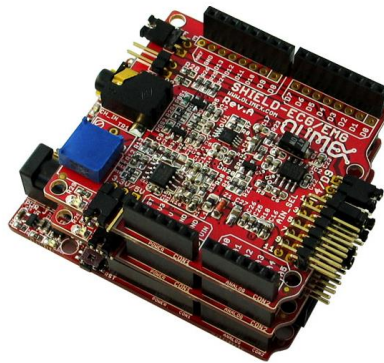


Figure 3. Shield EKG-EMG (Olimex)

This acquisition module is based on the INA321, which has a CMRR of 94 db, which is above the recommended value, which is 90 db minimum [3].

The recording of the electrical activity of the muscles was made by the analog-digital converter of an Arduino UNO. Figure 4 shows the signal EMGs corresponding to the long supinator muscle (channel 0) during an isometric contraction.

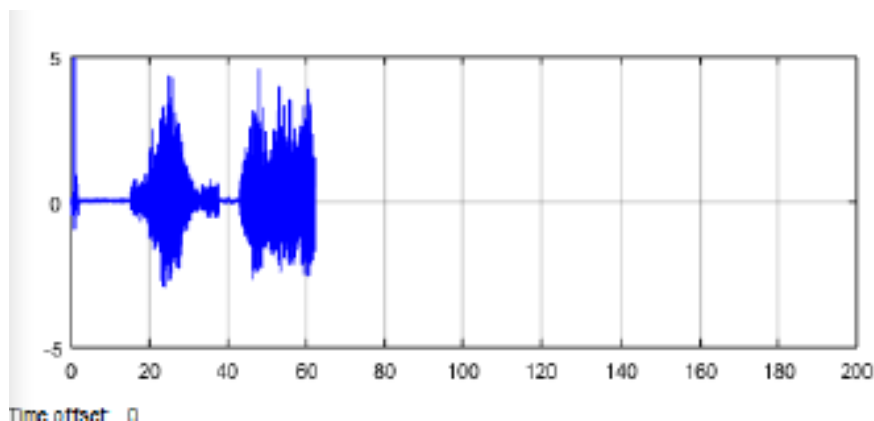


Figure 4. Isometric contraction of the long supinator muscle

In order to evaluate the signal in the time domain, during the acquisition, the implementation of a vector of 10 elements was performed, as shown below.

```
// data capture up to 10 samples
// channel A0 - muscle 1 (m1)

valorSensor0 = analogRead(A0);
valorEmg0 = map(valorSensor0, 0, 1023, 0, 255);

// Rectification of channel A0
v_rec0[num] = abs(valorEmg0-127);

// channel A1 — muscle 2 (m2)
valorSensor1 = analogRead(A1);
valorEmg1 = map(valorSensor1, 0, 1023, 255);
```

```
// Rectification of channel A1
v_rec1[num] = abs(valorEmg1-127);

if(num == (muestras - 1)){
//cálculo de RMS y VAR en cada muestra
    emg_feature ( );
    num = 0;
}
num = num + 1;
```

As we can see in the previous code, the channels A0 and A1 of the converter are read, and then the rectification of the signal is carried out. Having the rectified signal, the function `emg_feature ()` is called for the calculation of the characteristics.

2.3. Characterization of the EMG signal

Characterization on time domain is done because the control module must be accessible, which is achieved, in part, making its development using open source hardware platforms like Arduino, that don't have high data processing needs so it will not be expensive to obtain the final product.

The extracted features: Root Mean Square and the amplitude variance. These were calculated on each channel vectors. The formulas are the following [4]:

$$RMS = \sqrt{\frac{1}{N} \sum_{n=1}^N x_n^2} \quad (1)$$

$$VAR = \frac{1}{N-1} \sum_{n=1}^N (x_n - \bar{x})^2 \quad (2)$$

Then, it's shown a piece of the developed function code to calculate those values:

```
float emg_feature( ){
    for (int i=0; i<muestras; i++){
        suma0 = suma0 + v_rec0[i];
        suma1=suma1+v_rec1[i];
    }
    promedio = suma0/muestras;
    promedio=suma1/muestras;
    for (int i=0;i<muestras;i++){
//canal 0
        volt_sqr0 = v_rec0[i]^*v_rec0[i];
        sumasqr0 = suma_sqr0 + volt_sqr0;
//
        des0 = v_rec0[i]-promedio0;
        suma_des0 = suma_des0 + des0;
//canal 1
        suma_sqr1 = suma_sqr1 + volt_sqr1;
```

```

    volt_sqr1 = v_rec1[i]* v_rec1[i];
    //
    des1 = v_rec1[i] - promedio1;
    suma_des1 = suma_des1 + des1;
}

media_sqr0 = suma_sqr0/muestras;
rms = sqrt(media_sqr0);
var_x0 = suma_des0/(muestras-1);
media_sqr1 = suma_sqr1/muestras;
rms1 = sqrt(media_sqr1);
var_x1 = suma_des1/(muestras-1);

```

This function finally returns four values that conform two vectors, each of them giving information about the contraction level of the muscles (power and strength).

$$v_{m1} = [rms_{m1} \quad var_{m1}] \quad (3)$$

$$v_{m2} = [rms_{m2} \quad var_{m2}] \quad (4)$$

2.4. Analysis of position

To determine the position of the servomotor that turns the wrist (pronation and supination) the vector resulting from the characteristics vectors was taken, this being the difference between the two vectors (from the two muscles).

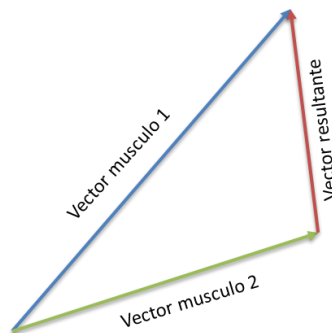


Figure 5. Vector sum between feature vectors

Being the resulting vector:

$$v_{res} = v_{m1} - v_{m2} \quad (5)$$

This difference can be appreciated on figure 6, where there is the electric activity registry of the antagonistic muscles during forearm movement. First, the supination movement is present where the long supinator muscle contracts and the round pronator relaxes; then the pronation is made where there is a low level of contraction for both muscles. Finally, during the pressing movement of the hand it is appreciated a strong contraction on both muscles.

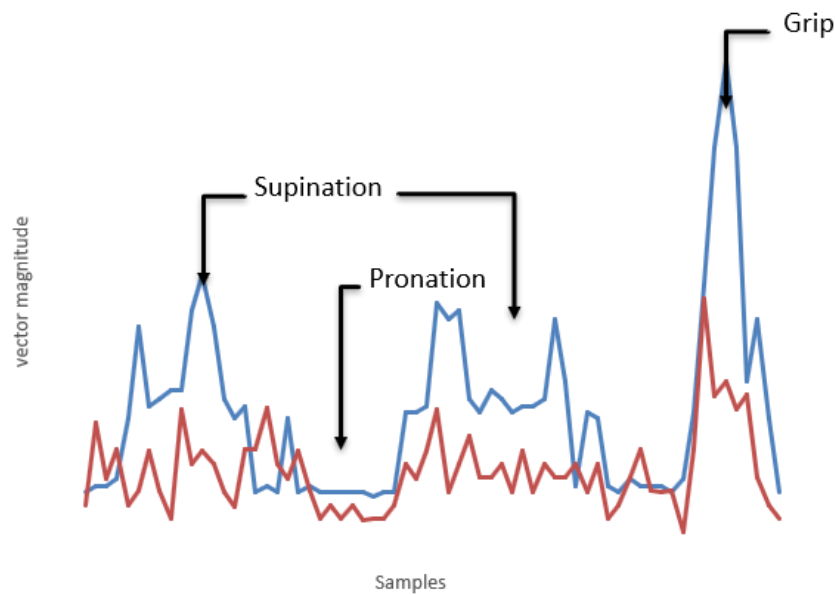


Figure 6. Forearm movement

Using the behavior on the magnitudes of the characteristics vectors a relationship can be obtained between the resulting vector and the PWM signal generated from the Arduino.

3. Results

Hereafter, it is presented the PWM signal generated from the EMG signal analysis. The PWM signal was not generated for any specific servomotor because the working range can be adjusted correlating the maximum amplitude value obtained on the resulting vector with the maximum width of the pulse.

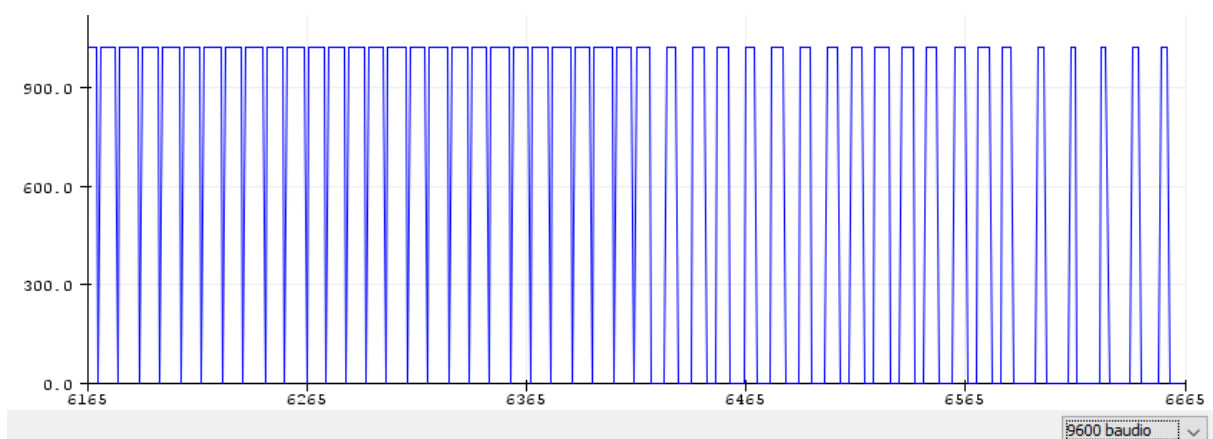


Figure 7. Pronation movement with an open hand

On figures 7 and 8 it is appreciated the PWM output signal according to the movements done by the forearm. On the first, it is seen the movement of pronation on the forearm and this is done with the hand open, so activation of the servomechanism that open and close the tweezers is not done. On figure 9, during the supination movement the hand is closed, so the tweezer servomotor is activated.

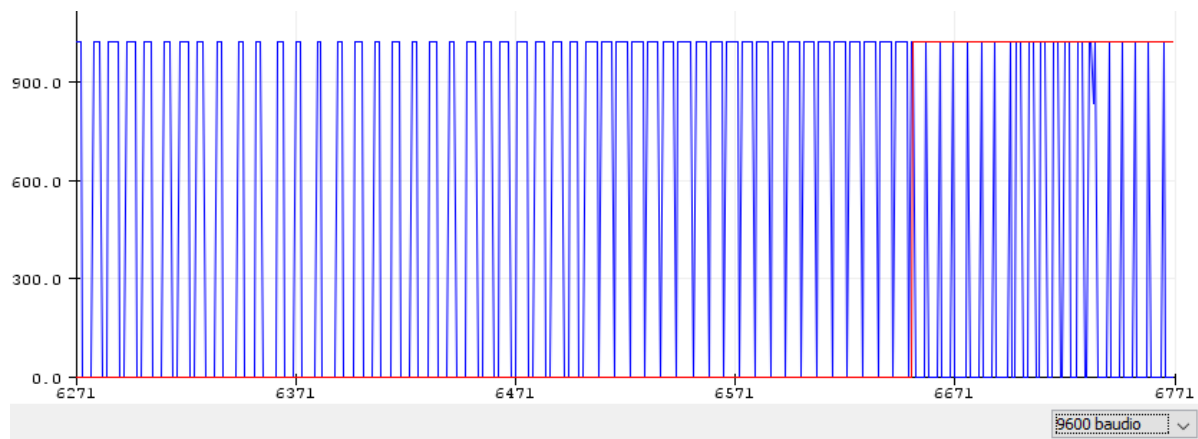


Figure 8. Supination movement and hand closing

4. Discussion

Based on the obtained results, a control system based on the time domain analysis is an economic alternative for the development of prosthesis that are accessible for people with low purchasing power. Even so, the control system must take in mind that the rapid variation of the signal produces errors on the servomotor position and this can be compensated with a bigger sample vector (number of obtained samples) being able to soften the oscillations produced on the signal or using working intervals for the resulting vector so the variation can be limited to these intervals.

A system that analyzes the signal on the frequency domain would make the system more expensive but can give a better control of the system, even though this can be used for control modules that are more robust directed to other type of population.

References

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