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Use of Myoelectric Signals in Hand Prosthesis

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Abstract: The electromyographic signals (EMG) or also known as myoelectric signals are electrical signals produced by movement of contraction and relaxation of muscles. Since they can be generated voluntarily, are widely used for their functionality to control human - machine interfaces. Investigations relating to the acquisition of these myoelectric signals have been used mainly for the purpose of operating various prosthetic devices for different type of limbs. Obtained as a result, this kind of prosthesis can be handled through the response generated by these signals to emulate the natural motion of the limb replaced. A human being is primarily a functional entity and his body and intelligence are the essence of what it does. The main organs for the physical manipulation of the environment are the hands[1]. The hand has been the key partner of the brain to turn thought into an action; in it, the ideas are mechanically translated into an action, creating hierarchical representations to configure the necessary processes in the control of movement[2].

Keywords: Electromyographic Signals, Myoelectric Prosthesis, Contraction and relaxation.

INTRODUCTION

The human body contains about 650 muscles, which together make up about 40-50% of body weight, they were classified into three types according to their character: smooth muscles or visceral muscles (produced slow contractions and involuntary movements), cardiac/heart muscle (causing fast and strong contractions and involuntary movements) and striated muscles or skeletal muscles (high-speed contractions and voluntary movements), the latter being the most abundant in the human body, being that it shape the 90% of all muscles, while only the remaining 10% is made up of cardiac and smooth muscles[3].

The striated muscle is called due mainly to the similarity with the fibers forming the assembly with a long cylindrical shape and having a length range from 0.1 *cm* to 30 *cm* with a diameter of 0.01 *cm* to 0.001 *cm*. ; which in turn consist of even smaller fibers called as myofibrils formed of thick myofilaments made of myosin and thin myofilaments made of actin, which are arranged along an overlapping manner each other, producing the characteristic pattern of bands or stripes of this type of muscle[4] (Figure 1,).

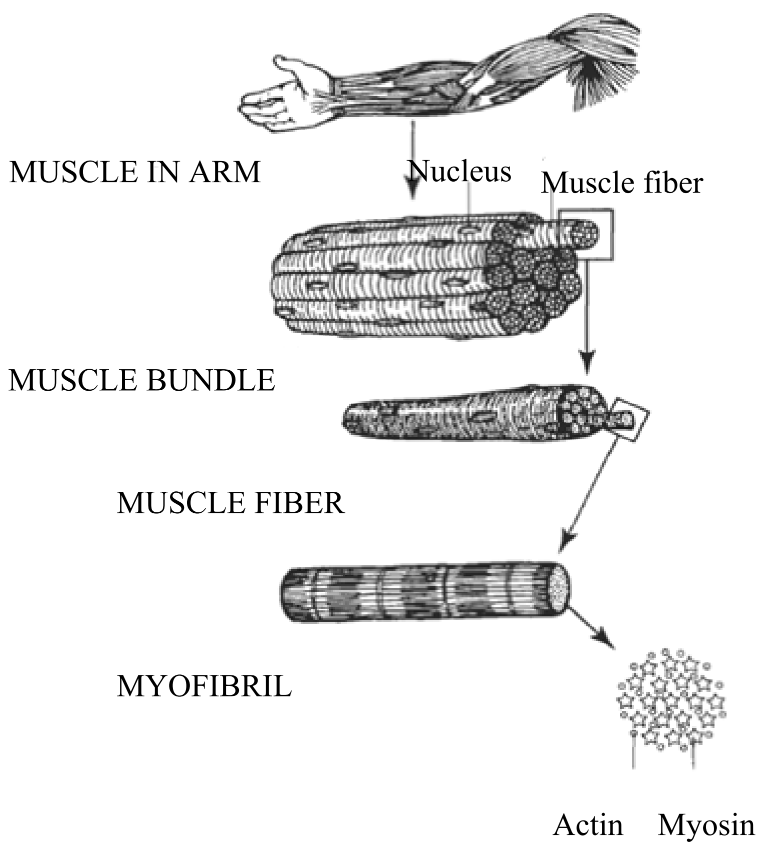

Fig.1: Sketch of parts that make up a striated muscle.

To perform a relative movement in the human body, the striated muscles are attached to bones in two join points, acting in coordination with various sets of muscles during the contraction and relaxation thereof. The muscle contraction occurs as from the sliding of inner filaments due to the interaction between actin and myosin myofibrils. Under resting conditions, these forces are in equilibrium, but when an action potential travels through the muscle fiber that produced a release of large amount of calcium ions to active the fibers, which in turn generates shrinkage forces on the fibers muscle[5]. While the end of the muscle, which is connected to the reference bone from which the motion is generated, is referred to as origin, the other end of the muscle is known as an insertion. Depending on the functionality of muscle involvement in the movement performed, these are classified as primary muscles, antagonists, synergists and fixatives[6] (Figure 2,).

The bioelectric signals or action potentials moreover are the result of activation of the muscle fibers induced by the contraction or relaxation of muscles in the human body. This signal differs in general of any other signal in the body by having four stages: a resting stage, a period of excitation (depolarization), an absolute refractory period and relative refractory period, being these steps in function of the action potential of the muscle fiber referred[5].

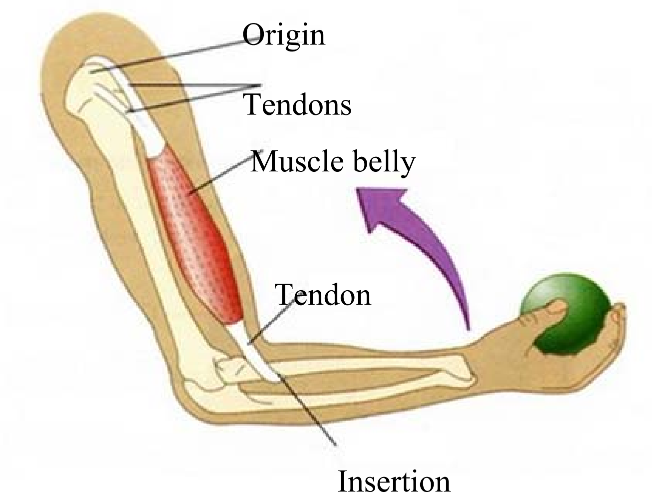

Fig.2: Fixing a skeletal muscle involved in flexion and extension of the forearm.

These action potentials are caused by the depolarization of myofibrils due to the activation process generated by the central nervous system, during which electric shocks occur owing a change in the voltage potential membrane, ranging from the negativity of the resting state to positive values for a short lapse time, to which being known as myoelectric signals. Such signals, despite having small voltage levels can be measured so that the information gathered is used for various purposes, such as diagnosis of diseases, monitoring vital rhythms, and even manhandling machine interfaces such as recovering a lost limb (prosthesis).

Depending on the monitored organ, the electrical signals that cause contraction of the muscles involved in the movement there of is specifically called, so in Table 1 the general description of the average values reported by various sources is shown. It should be mentioned that surface *EMG* signals (*EMGS*), are essentially a one-dimensional pattern, so that any signal processing technique for feature extraction and pattern recognition can be applied to such signals.

The main objective of this study was to determine the proper position on where to place the electrodes along the upper member so as to achieve define a stable zone, where to obtain an electromyographic signal allowing control to simulate a cylindrical grip when gripping a glass of water for the upper arm prosthesis as shown in Figure 3, so that its location requires the correct identification of muscle regions involved in the execution of the movements to be performed.

This is because as mentioned in[7,8] performing a specific motion activated a set of muscles through which the full position of the member influenced in the force exerted by this is generated, and so directly modify the intensity of the signal generated.

Table 1: Type of bioelectric signals: Magnitude and Bandwidth.

SIGNAL	MAGNITUDE (μV)	BANDWIDTH (Hz)
Electrocardiogram (ECG)	500 – 4000	0.01 – 250
Electroencephalogram (EEG)	5 – 300	DC – 150
Electrogastrogram (EGG)	10 – 1000	DC – 1
Electromyography (EMG)	100 – 5000	DC - 10,000
Electrooculogram (EOG)	50 – 3500	DC – 50
Electroretinogram (ERG)	0 – 900	DC - 50

Fig.3: Proposal of measuring myoelectric signals during developing a cylindrical gripping of power.

METHODS

There are different ways to achieve the acquisition of the *EMG* signals in the diverse types of muscles, either invasively by needle electrodes grafted directly on the muscle to monitor or noninvasively using surface electrode[9], taking into account the number of electrodes corresponds directly to the number of channels to be processed and therefore the number of movements to the model[10].

Usually, the *EMG* signals are typically collected using bipolar electrode surface, which are placed on the skin, which due to the high natural electrical resistance of the skin, applying a gel to improve the conductivity is recommended also achieved better surface contact and adhesion to the electrodes[11].

According *Sarmiento* in[2] must be identified the muscle actuator with the artificial electrodes so together with the reference achieve a measurement threshold at which the muscle contraction of the movement is exceeded, so they are located on the common flexor on the fingers, although *Dorador* in[12] mentioned that the location on the surface electrodes to capture the myoelectric signals should be in the region of the biceps.

Subsequently, the signals collected by the sensors to be too low for proper interpretation, go through a stage of filtering and amplification.

The main origin of noise interfering with myoelectric signals are usually due to capacitive interference from the patient, and also inductive interference caused primarily by the power supply the measuring device, which produce magnetic fields that vary with the time, which in turn induced voltages in the network formed by the electrodes from the patient[11]. According to *Cifuentes*[13], the filtering step for myoelectric signals should consider analog filters in a frequency range of 10-500 *Hz*, while in[14-16] states that you must attach a filter rejects bands of notch around 50 or 60 *Hz* through the *Notch* filter, thereby blocking common signal 50/60 Hz of the electrical network. Alternatively, according to[17] needed to use an active bandpass filter to the fourth order among 10 and 500 *Hz* for purifying of the myoelectric signals. In[11] digital filters were implemented using a simple high-pass filter, the majority of these filters are called *Lynn* filters and they are described in[18] and applied to the processing of electrocardiographies signals in [19,20], *Lynn* filters have a High Pass and Low Pass version.

During the amplification step of the myoelectric signals captured, according to previous studies should be considered a range of amplification of at least 500 to 1000 times[10,11], which is obtained by operational amplifiers that increase the magnitude of these signals and been sent to a data acquisition board [21].

According to *SENIAM* regulations[22] is recommended that bipolar surface electrodes are located with a distance of average separation between centers among 20 *mm* and 30 *mm*, and if placed on relatively small muscles, the electrode spacing must not exceed 1/4 of the length of the muscle fiber, this in order to avoid the area of tendons and muscle fiber terminations.

For example, in the work presented by [23] is mentioned that in order to distinguish different *EMG* signals concerning the movements made by the fingers is used a predictive learning method referred to as *SVM* or support vector machines, by which could characterize 11 independent hand movements, which could apply these pattern recognition for controlling robotic hand *DLR HIT*.

It is also important to consider when analyzing the signals obtained the movement type performed by muscle monitored because isometric movements and exercises that require static positions the signal obtained will should be considered under conditions of large time (usually> 150 *ms*), while during dynamic movements the time constants used will should be chosen with an average of 60 *ms* or less[24].

The forearm extends from the elbow to the wrist and consists of 2 bones the (lateral) radius and ulna (medial) Figure 4(a), are united by the interosseous membrane that divides the forearm muscles in anterior action and back action, Figure 4(b) so that the flexor-pronator muscles lie ahead and extensor-supinator turn behind, the proximal portions of these muscles are inserted into a bony extensions of the humerus (medial epicondyle to flexor-pronator and lateral epicondyle to the extensor-supinator). In general, the anterior compartment muscles are innervated by the median nerve and the posterior compartment are innervated by the radial nerve; see Figure 4(c). The forearm muscles acting on the elbow, wrist and fingers. For these reasons, and considering the location proposed by[25], is placed four pairs of electrodes on the forearm as shown in Figure 5.

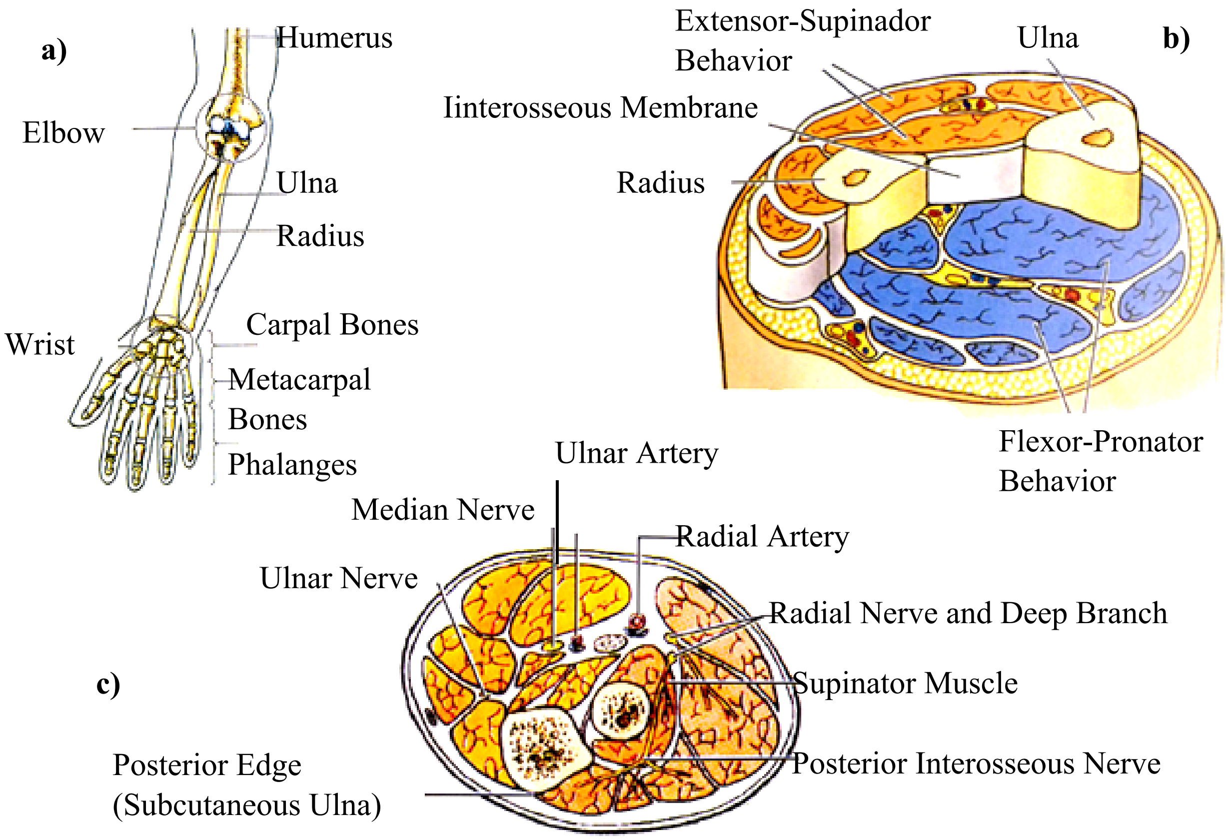

Fig.4: a) Bones of the Forearm. **b)** Cross Section of the Forearm where it Shows the Interosseous Membrane and the Two Groups of Muscles, Flexors and Extensors. And **c)** Medium and Radial Nerves.

Fig.5: Approximate position of the electrodes in the forearm muscles signaled by[25]

Subsequently, the measurement of *EMGS* signals recorded with the oscilloscope, are shown in the following images:

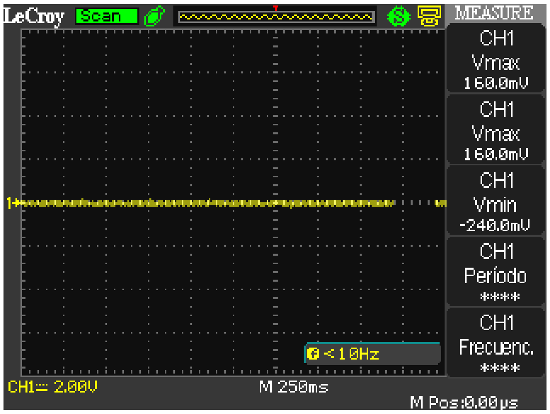

Fig.6 Signal Obtained from the Muscle in Rest.

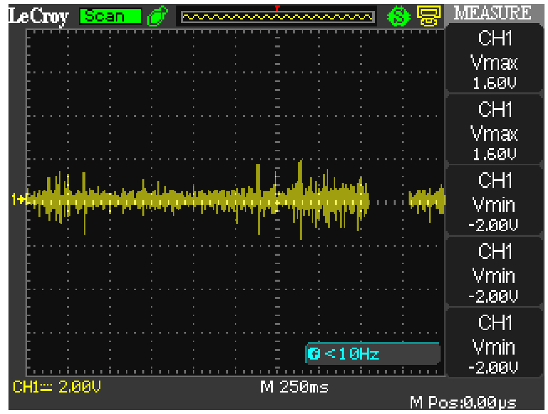

Fig.7 Signal Obtained from the Muscle in Medium Effort.

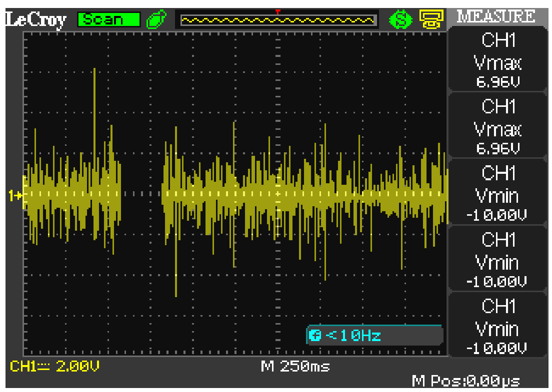

Fig.8: Signal Obtained from the Muscle in Maximum Effort.

RESULTS

Finally, in the following table are shown the results obtained for the measurement of the electromyographic signal of muscle controlling the index finger during a bending, at a height of 50 to 75% of the total length of the muscle.

Table 2: Parameters Obtained with Surface Electrodes from the Signal Muscle.

TYPE OF MAGNITUDE	MAGNITUDE 50%	MAGNITUDE 75%
Vpp	8.4 *V*	2.16 *V*
Vmáx	3.60 *V*	1.04 *V*
Vmin	-4.80 *V*	-1.12 *V*
Approximate Period	26 *ms*	15 *ms*
Approximate Frequency	38.46 *Hz*	66.66 *Hz*
Rise time	17 *ms*	6 *ms*
Fall time	5 *ms*	268 *ms*

CONCLUSIONS

Considering these values of electric potentials is remarkable to see how a small variation of 25% in the position of the electrode reaches appreciable influence on the obtained signal, and as noted in[26] the largest type of grip used in everyday life is the cylindrical type, whereas the activity that more was devoted time was to eat as well as the tasks arising from this, to which on average will dedicate a total of 1.15 hours a day at it is important to determine in future studies the pattern of the myoelectric signals and the set of muscles involved in the development of the types of grips reported by them, same as they are reproduced in Table 3.

Table 3: Daily frequency of use of various types of grips.

GRIP	DAILY FREQUENCY OF USE
Cylindrical	12.3%
Oblique	6.0%
Hook	3.1%
Lumbrical	10.0%
Intermediate Precision	3.2%
Clamp	37.2%
Lateral Clamp	9.2%
Special Clamp	2.8%
Not Prehensile Movement	12.9%

From these values it intends to develop for future work the design of the card data acquisition that will be used to using the control software developed for this project, the servo motors of the prosthesis are activated by pulses generated by *EMG* signals by detecting the value of the potential and thus the muscle where it originated and predict patient movement and want to emulate it like a real muscle with a natural hand, Figure 9.

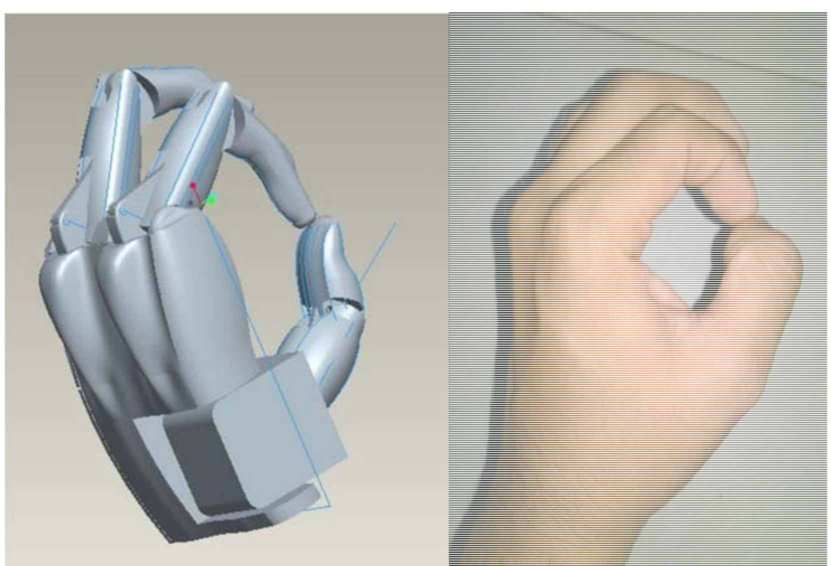

Fig.9: Simulation of the prosthesis emulating the trajectory of hand movement.

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