Intelligent Prothesis of Hand Controlled by Artificial Neural Network

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Exposition of the Problem

The amputation of extremities constitutes the fourth cause of incapacity of the population of the country.

The majority of the cases are due to diseases such as diabetes, although the amputations of the superior extremities are almost always derived from industrial accidents.

Based on the previous data, a series of investigations and technological development were carried out in order to design and implement an intelligent interface for the control of an electromechanical prothesis of an arm and hand.

Exposition of the Problem

In Mexico, according to the National Institute of Geography and Computer Science, in the year 2000 there were 813 thousand people in the country with a motor incapacity, without specifying the type: amputated, paralytic, paraplegic and quadriplegic persons, among others.

The health sector does not possess statistics regarding the population presenting these types of physical loss, but it is known that many are a result of diabetes, accidents and cancer.

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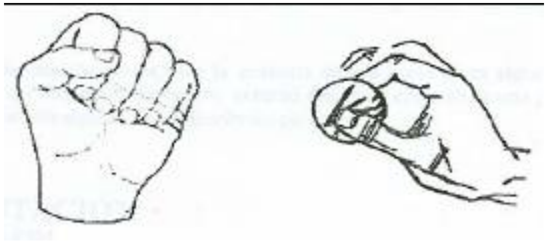
Introduction

- In the last years, investigations directed to the accomplishment of man-machine interfaces especially designed to aid people with incapacity or to execute tasks without the need of direct contact from the worker, have acquired great importance.

- One of the ways of accomplishing this goal is by picking up the electromyographic (EMG) signals from the muscles, which are qualitatively associated with the type of movement produced.

Introduction

- The hand has two fundamental functions: the handgrip and the upper clamp.



Mechanical functions of the hand.

- The main movements of the thumb are: flexion, abduction, extension and opposition.

Thumb movements.

Introduction

- Although some studies focused on the electromyography analysis do exist, they take a long time between obtaining the signal and classifying the movement to be executed by the prothesis, making their implementation for the control of real devices unacceptable.

- Other studies describe methods which classify the signals faster, but whose implementation requires long days of training for the patient in order to learn how to handle the prothesis and generate the muscular contractions which are not normally used in a natural member.

State of the Art

The study of these signals has allowed important projects seeking human well-being to be developed. They began with those done by Graupe and Cline in the recognition of characteristics in 1975, followed by Doershuck who applied correlation techniques in 1983. In 1995, Kang used cepstral coefficients obtaining a success index of 85%. As of 1999, the NASA Neuro-Engineering department developed EMG pattern recognition techniques by means of neural networks and hidden models of Markov. In 2002, Fergusson and Dunlop developed characterization techniques for EMG signals based on STFT (Short Transformed Fast of Fourier) parametric modeling , wavelets, recognition with neural networks and using statistical methods. In the year 2003, prothesis training was done along with the prediction of fatigue in muscles and the optimization in the design of the pattern recognition algorithms in real time.

State of the Art

Currently, research in this area is focused on finding the processing, characterization and pattern classification algorithms of these signals, allowing the analysis and determination of the type of movement to be made with success percentages between 80% and 97%, depending on the number of electrodes used and the amount of detected movements.

Goals

General Goals:

- To design, construct and control a robot hand controlled by myoelectric signals.
- To design and implement an electronic system with an intelligent algorithm able to identify the basic hand movements and to control them in an electromechanical prothesis, based on the study of the myoelectric signals from the forearm of patients with proximal amputation.

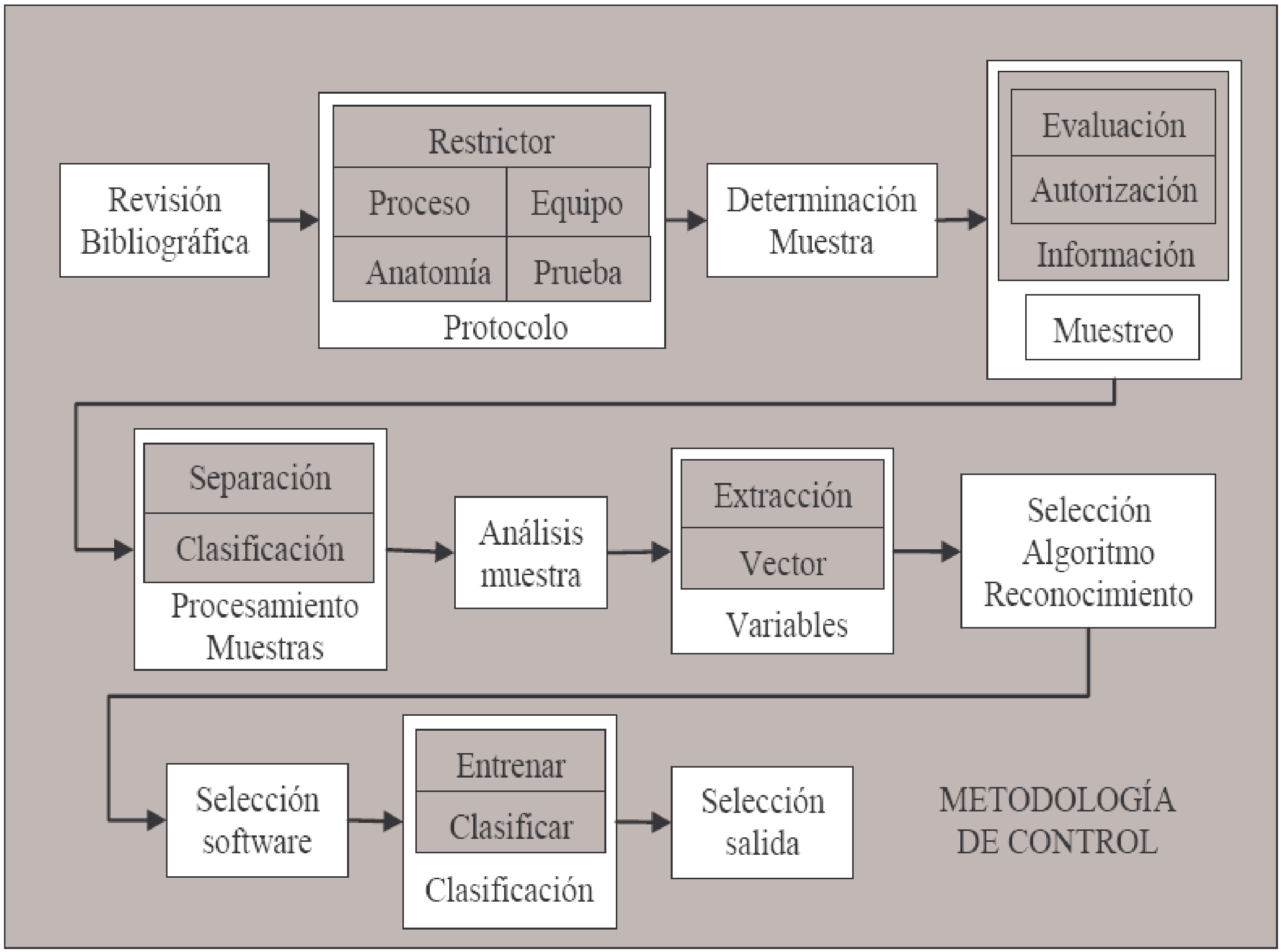
Goals

Specific Goals:

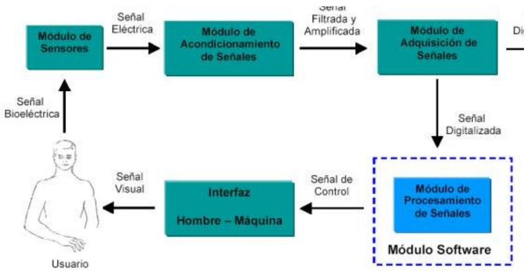
- To analyze the myoelectric signals using time series techniques.
- To design and construct a circuit that amplifies the signals.
- To design the control system.
- To design and construct the robot hand prototype.

The implemented algorithms using continuous acquisition techniques in real time, the hybrid characterization techniques in time and frequency using the transformed Wavelet, the Fast Transformed of Fourier (FFT), the Short Time Fourier Transformed (STFT) and the parametric modeling in the analysis of myoelectric potentials. And the pattern recognition using an algorithm based on a neural network.

Basic Methodology for the Proyect

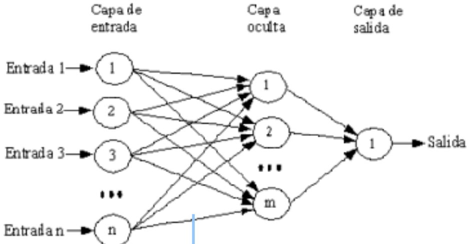


Architecture of the Project



Interface for obtaining the myoelectric signals by electromyography EMG

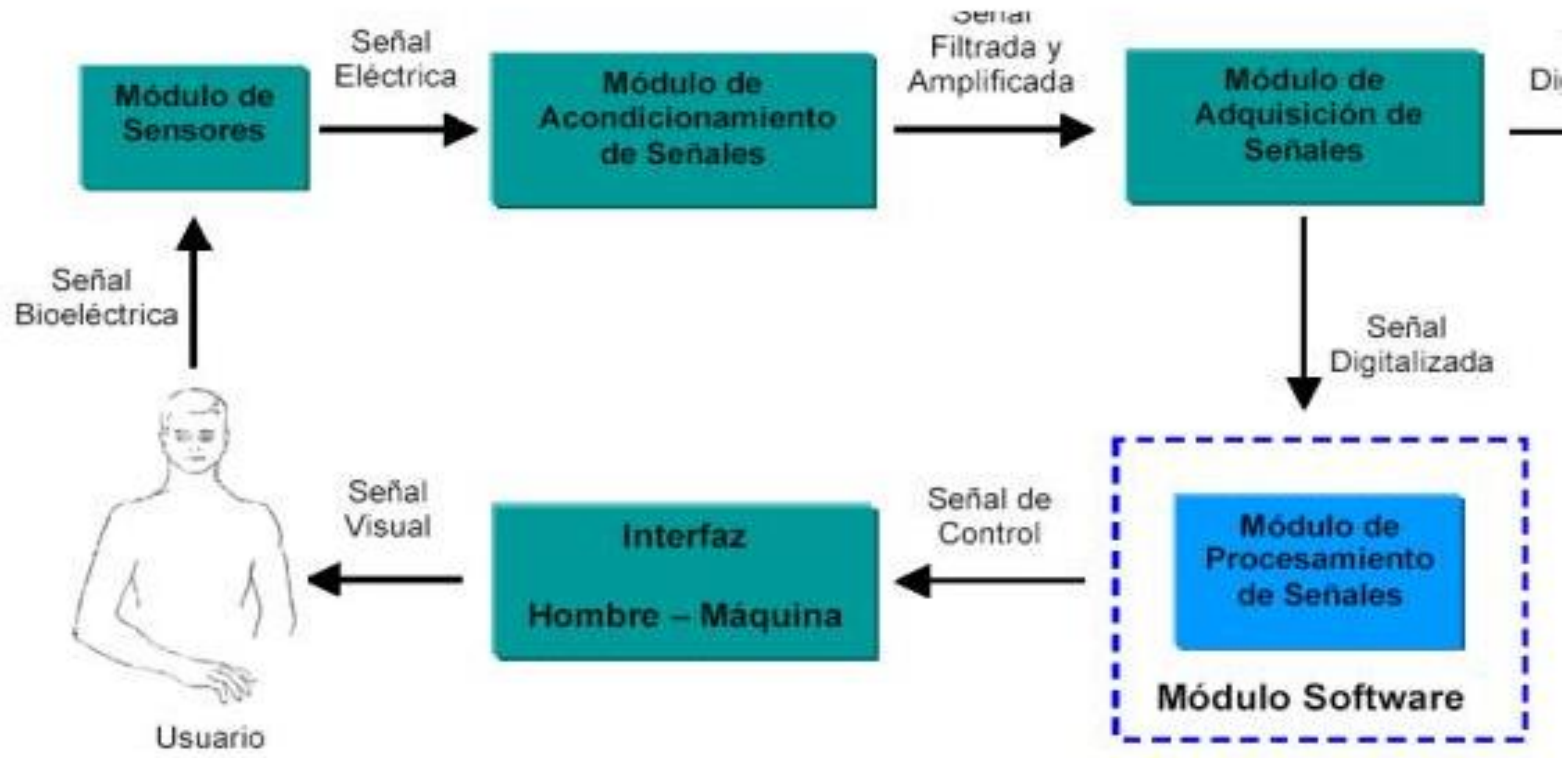
Processing Signals



Artificial Neural Network

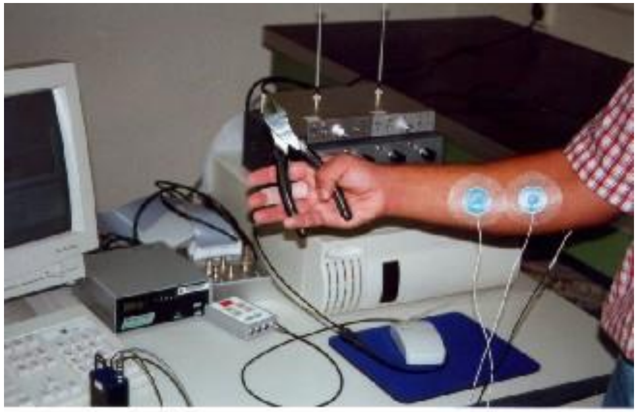
Sending signals for the movements of robotic arm

Electromiography EMG



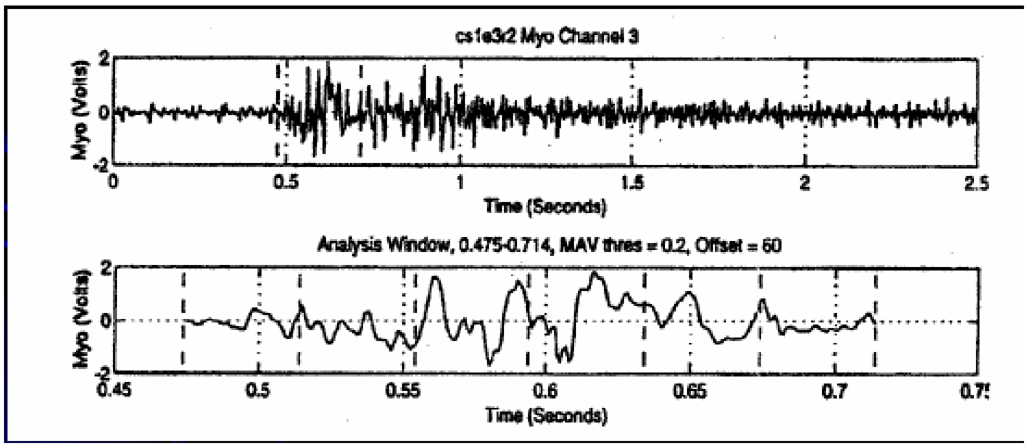
Electromyographic (EMG) Signals

The electromyographic signals (EMG) are electric signals produced by a muscle during the contraction and relaxation processes. This muscular characteristic is meant to be taken advantage of in the control by means of a computer in order to create alternate communication interfaces between the user and the machine, than the already existing ones such as the keyboard and the mouse. An interface of this type would allow any user to control computer science and/or electronic systems through the contraction of certain muscles.



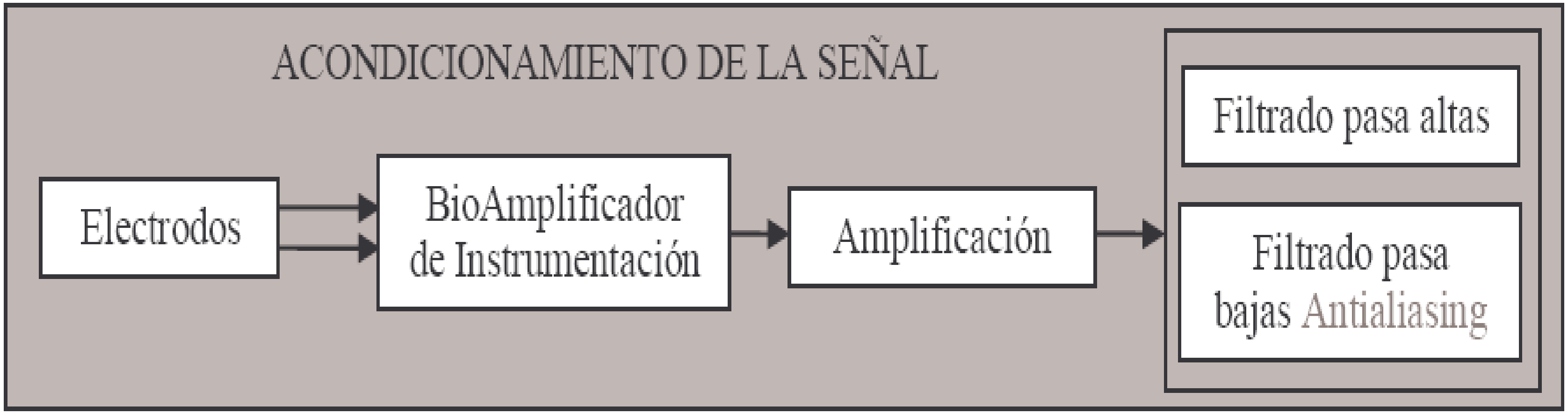
EMG

- The myoelectric signal (potential of motor action) is an electric impulse that produces the contraction of the muscle fibers in the body. This term is often used to refer to the body muscles that voluntarily control movements.



Myoelectric Signal

Signal Preparation



Location of the Electrodes

- The myoelectric signals are detected by placing three electrodes on the skin. Two of the electrodes are placed in such a way that a voltage difference is produced between them when a myoelectric signal occurs. The third electrode is placed in a neutral area and its exit is used to cancel the noise that can interfere with the signals between the other two electrodes.

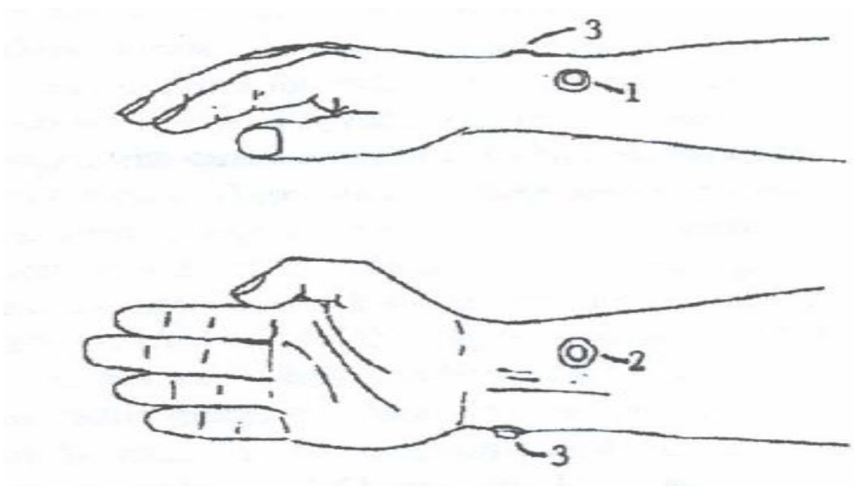
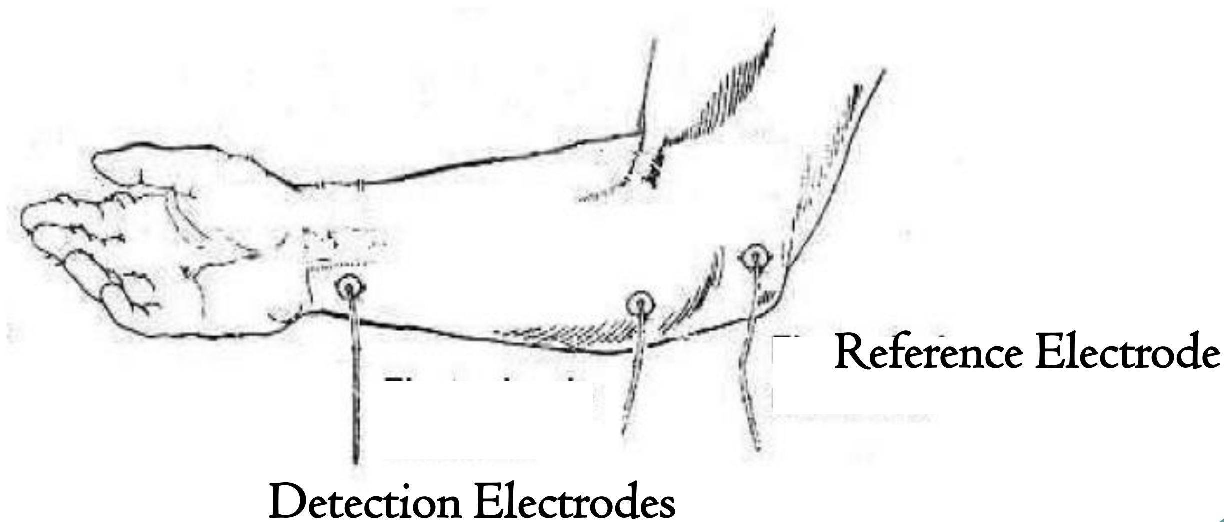


Fig. 2 Location of the electrodes

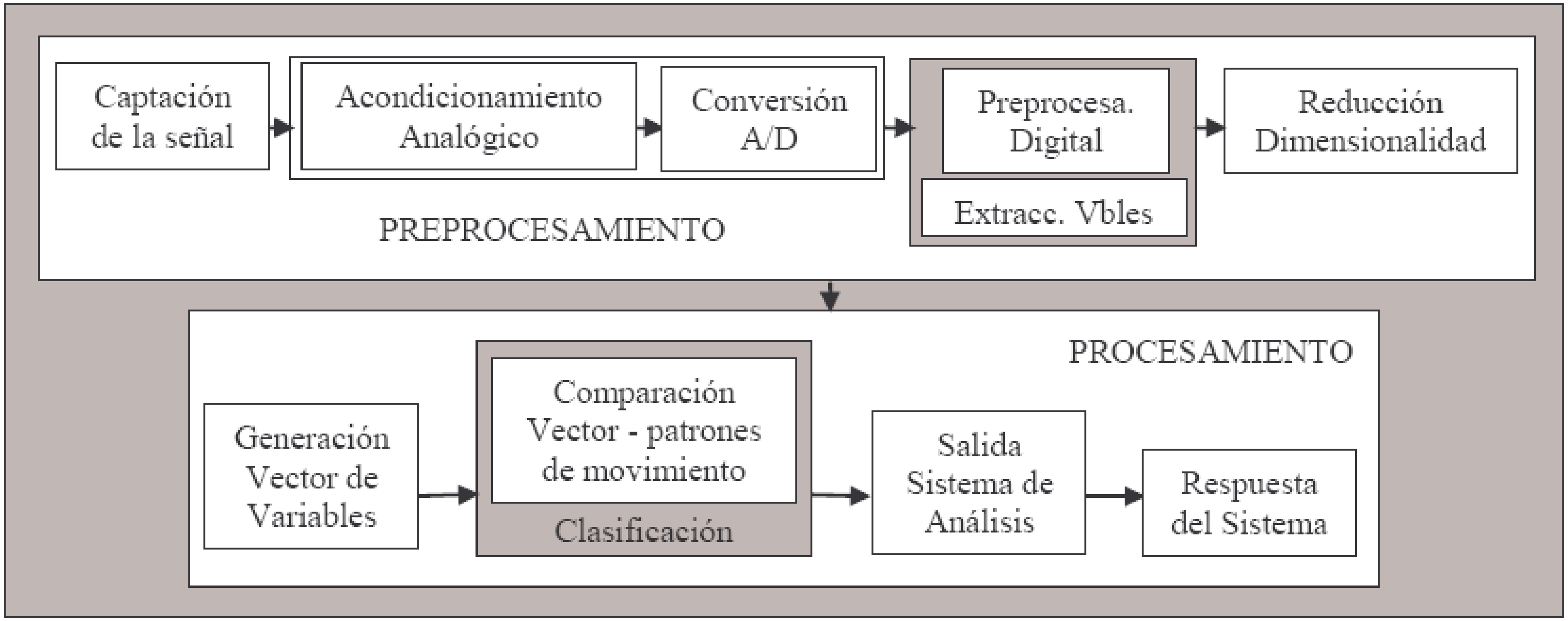
Location of the Electrodes

- The most important aspects related to the acquisition and the analysis of EMG surface signals were recently covered in a multinational consensus called SENIAM: Surface EMG for the Non-Invasive Assessment of Muscles, in which the electrode construction and its location were thoroughly discussed.

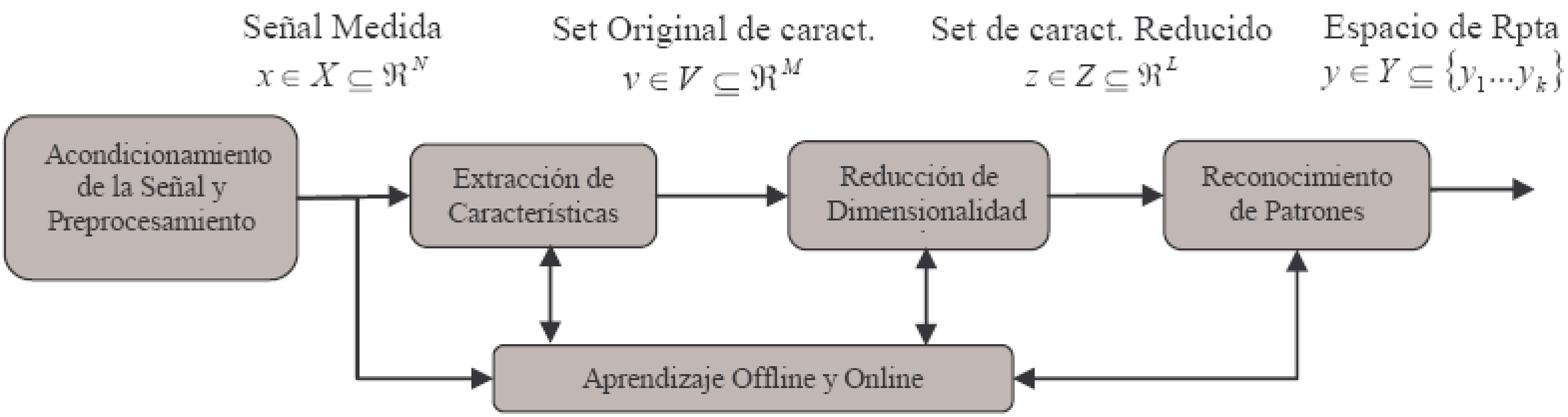
  Hargrove L.



Sequence of Events to Obtain the EMG Signal for its later Analysis



Treatment Methods



- Rectificado
- Filtrado
- Detección Umbral

- MAV
- AVR
- IAV
- Varianza
- WL

- Coeficientes AR
- STFT
- WT
- WPT

- Proyección Características
- Selección Características

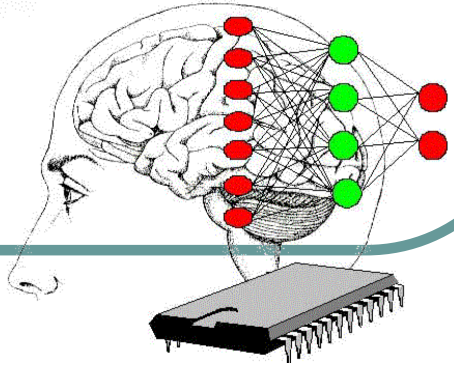
- Patrones Bayesianos
- ANN
- Lógica Difusa
- Sistemas Neuro Difusos

Zecca et al, 2002

Artificial Neural Networks

Upon obtaining the coefficient data, a *feedforward* type artificial neural network trained with the *backpropagation* algorithm will be used to classify these coefficients which represent the signals.

The functionality of a neural network is determined by the interconnection between its elements. This, in turn, can be trained to carry out a specific task through the adjustment of its parameters. The signal classification, according to the type of movement that it produces, is carried out by associating the coefficients to the specific type of movement as it corresponds to previously identified signals. Training sets, validation and entrance-exit tests will be created for each movement, respectively. The training will be controlled and supervised in order to avoid *overtraining* with the validation set.



Artificial Neural Networks

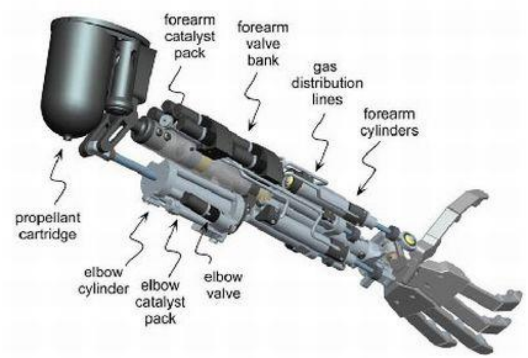
This way, the neural network becomes generalized and open to data which was not previously introduced to the network. This association will be carried out using the *backpropagation* algorithm. Therefore, this type of network is chosen for the classification and the network that is obtained must present the best performance compared to other results. Since a greater number of neurons do not show better results, it is considered a success if one of the network exits is active and the rest remain inactive. When either more than one exit or no exits at all are active, the result is defined as "No Class", in which the network was unable to identify the type of movement.

Advantages of Artificial Neural Networks

Due to their construction and bases, the Artificial Neural Networks present a great number of similar characteristics to those of the brain. For example, they are able to learn from experiences, to generalize from previous cases to new ones, to abstract essential characteristics from input that represents irrelevant information, etc. Thus, upon offering a great number of advantages, the Artificial Neural Network technology is being applied in multiple areas.

Some advantages include:

1. Adaptive Learning
2. Auto-Organization
3. Tolerance to Failure
4. Operation in Real Time
5. Easily adapted to existing technology



Experimentation

Until now, the techniques used in other experiments have obtained a success of 90%, which is why the goal is to elevate this success index by applying combined techniques of neural networks and expert systems.

This approach is due to the great behavior of the neural networks in dynamic systems because of the fact that the system, after having received some initial patterns, begins to identify, accept, learn and respond to different signals even though these are not identical to the initial patterns. This is precisely what the most suitable hypothesis for the initial work on interfaces is based on, as is the present project that, in addition, must be personalized for each patient.

Software Development

The software development is carried out using an intelligent system (Artificial Neural Networks) that allows the movements which will be executed by the prothesis to be recognized from the myoelectric signals that are captured and processed.

The software development will be done in Matlab and the signal recognititon in Labview. Once the entrances and exits are determined to create the neural network, it will be programmed in C and, at the end, it will be programmed in the microcontroller.

MATLAB® C/C++ LabVIEW

Before being implemented, there will be a Neural Network training stage. The results obtained will provide the base for implementing the intelligent interface hardware.

Hardware Development

The electronic system is made up of the creation modules, the signal acquisition and conditioning, and the recognition and control of the electromechanical prothesis.

The robotic prothesis created is shown below:

Conclusions

The treatment methods of the EMG signal are considered starting off from the type of practices required for the signal taking, the signal preparation, and the EMG characteristics, until arriving at the classification algorithm to be used. Nevertheless, the most important element is to demonstrate the existence of patterns in the captured signals and, thus, the attainment of a protocol that validates those signals, making it easier to completely implement the methodology in order to observe how the neural network classifies the movements from the EMG. It was possible to thoroughly study the EMG signal and to extract the factors that affect them. From these elements, a protocol for the taking of EMG signals was designed and evaluated. This protocol can be modified to evaluate another type of muscles, in which case, it would be necessary to analyze the anatomy of that given area in order to determine the best location for the electrodes.

Future Research

As a follow-up of this study, applying the characterization techniques, validating the number of characteristics in order to diminish the computer cost and, in addition, implementing the recognition techniques, are expected. Since the characteristic patterns are clearly differentiable, the neural network training time is considered to be relatively short. It is clear that a single method for the myoelectric signal characterization is not very exact. The prothesis is being implemented with indispensable elements so that it may not only give substantial aid to an unilateral amputee, but may also satisfy the mobility and control facility requirements needed for a bilateral amputee. One hopes that the amputee does not reject the prothesis that has enough power to do most of the activities with the sufficient degrees of freedom to make it functional and an intelligent control. This way, one seeks that the prothesis not only fulfill the mechanical needs of the user, but may also allow the integration to his/her personal work and social surroundings.

Comments & Questions

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