

Electromyography Signal Acquisition and Analysis System for Finger Movement Classification

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Abstract—Electromyography (EMG) is very important to capture muscle activity. Although many jobs establish data acquisition system, however, it is also essential to demonstrate that these data are reliable. In this sense, one proposes a design and implementation of a data acquisition system with the Myoware device and the ATmega329P microcontroller. One also proved its reliability by classifying the movement of the fingers of the hand, with the help of the algorithm k-Nearest Neighbors (KNN) and the application of Classification Learner code of Matlab. The results show a success rate of 99.1%.

Keywords—EMG; muscles; disability; classification learner; Myoware

I. INTRODUCTION

In the national report of the socio-demographic profile¹, carried out by the Statistics and Informatics National Institute (INEI for its Spanish name), it mentions that in Peru 10.4% of the population suffers from some disability. From this population, 15.1% cannot move or walk. Under this problem, it is necessary to facilitate the taking of samples of the signals that occur during the movement, to build robotic systems that perform the actions that disabled people require.

Wyoware [1] was used to obtain data, which is an electro-diagnostic system to evaluate and record the electrical activity produced by the skeletal muscles. These sensors are used in prostheses, robotics, and much more. The Wyoware detects the electrical activity of the muscles, then convert them into a variable voltage that can be read on the analog input pin of any microcontroller, in our case the ATmega328P microcontroller.

The Wyoware device is an individual device which reduces the ability to pick up signals from different parts at the same time. This reason is why a basic system of securing 4 Wyoware is created, which will represent four channels of data acquisition. A sampling algorithm is also developed in Python, and another one for signal processing in Matlab focused on people partially amputated from the upper limbs.

In [2] an eight-channel, low-cost hardware system is developed focused on the acquisition of EMG data which validates using it for the classification of the signals, obtaining an 80% effectiveness.

In [3] an EMG data transmission system is developed wirelessly through FM antennas (modulated frequency), they have a two-channel system, one of which acquires EMG data and the other captures the data of the signals produced by the

carotid, in order to help regulate the proper flow of blood to the brain in war pilots.

In [4] a shield for Arduino one is developed, to acquire data of ECG, EMG, and EOG, which can be used together, which allows obtaining different types of signals.

In [5], a system is developed to read data from an Arduino board from Python, which allows extracting the characteristic curves of the signals.

In [6] they create a 5-channel system based on operational amplifiers, a signal acquisition system is proposed, from which nine characteristics have been extracted in the time domain and 7 in the frequency domain; which are classified with different algorithms achieving a precision that goes from 57.69% to 99.92%.

In [7] there is a summary of other works related to prostheses and EMG, advances in upper limb prosthesis technology, Adam's Hand electronics are described, a transradial myoelectric prosthesis does not say that the mechanism can act 15 degrees of freedom with a single motor. A bracelet with sensors and an Arduino system are used to obtain myoelectric signals.

In [8] a wireless four-channel EMG acquisition system with high precision, low latency is designed, they mention us that the sEMG (superficial electromyogram) characterizes the functional state of the human nerves and muscles to a certain degree; they allow to predict the force, to recognize the movements, as well as to diagnose muscular disorders.

Section II presents the methodology that has been followed for the research work. In Section III, one finds the preliminary results obtained. Finally, in Section IV, one presents the discussions and conclusions for this research work.

II. METHODOLOGY

For the present work, the methodology to follow is outlined in the block diagram shown in Fig. 1.

A. Wyoware

The Wyoware is a system that detects the electrical activity of the muscles, but it is complicated when it is positioned around the arm, therefore a fastening system was built; for this purpose, a 3D base was designed, in which the electrodes could be placed as you can see in Fig. 2. The slots have been placed on the sides in the edge which a strap will pass, so it could ensure that the electrodes are kept in a fixed position.

¹ INEI, "Perfil Sociodemográfico, Informe Nacional," 2017. [Online]. Available: http://censo2017.inei.gob.pe/publicaciones_especiales/. [Accessed: 27-May-2019].

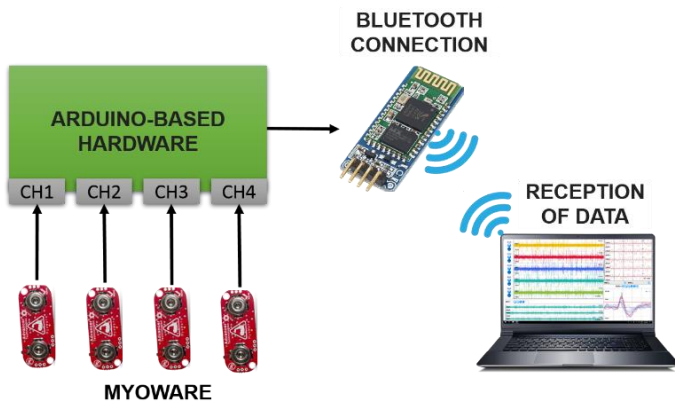


Fig. 1. Work Scheme

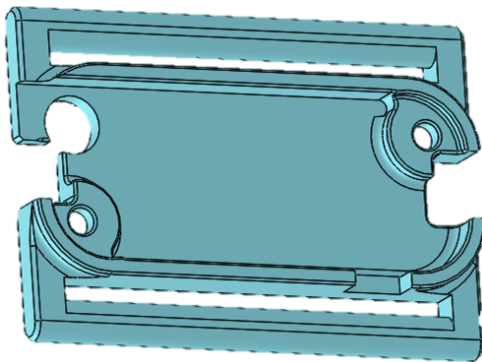


Fig. 2. Myoware Support.

This design, besides being able to be used on the arms, can be used on the legs, and other parts of the body where you want to study the signals of the muscles which represents an extra feature of the design.

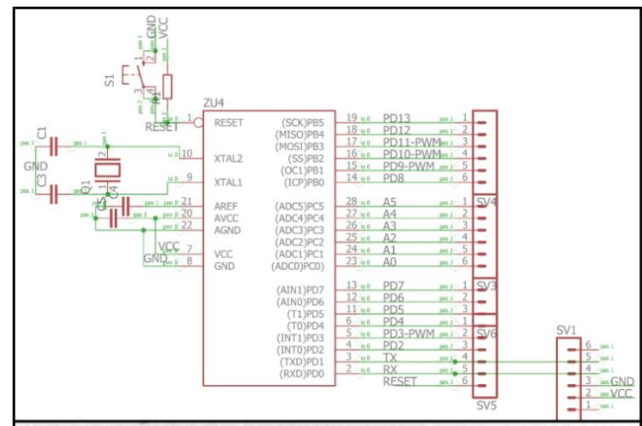
The Myoware has three main connections, of which 2 correspond to the power supply of the system with 5 volts and the last one is where the signals are sent in analog form, which can be acquired by microcontrollers.

B. Hardware Design and Implementation

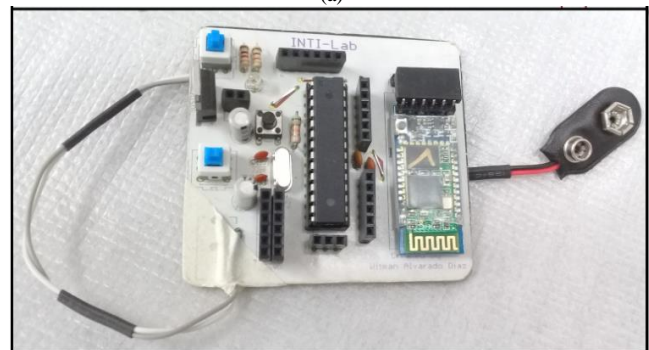
It is necessary to design an electronic system which allows us to capture the signals sent by the Myoware, based on the ATmega328P microcontroller, which is chosen by the ease with which it can be programmed based on Arduino one for recording in the microcontroller, the same bootloader that uses Arduino one, with this, the microcontroller can be programmed with greater ease.

In Fig. 3(a), the reader can see the basic connection diagram for the operation of the ATmega328P microcontroller, to this design, it added a power supply which provides continuous 5v to all the electronic devices; in the lower right part of Fig. 3, you can see the connection for the Bluetooth module HC-05. In Fig. 3(b), you can see the electronic system already finished, which has all the necessary connections for the operation of the system.

Additionally, in order to hold the electronic board created, a support was designed and printed in 3D, which you can see in Fig. 4.



(a)



(b)

Fig. 3. (a) Connection Scheme. (b) Electronic Board Completed.

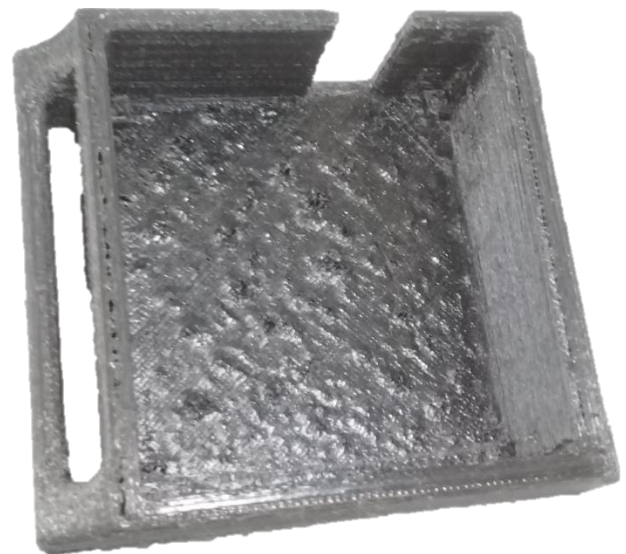


Fig. 4. Support for the Electronic Board.



Fig. 5. Bluetooth Adapter.

C. Bluetooth Communication

The Bluetooth connection as mentioned above is done through the HC-05 module and a Bluetooth adapter for the PC as USB type (Fig. 5), which is linked and connected to the HC-05 by a serial port in our case "COM4".

Once the data transmission devices are linked, the transmission of data corresponding to the readings of the Myoware starts; to verify that there is communication, you can use the PuTTY tool which opens the corresponding port in serial mode, and shows us the receiving data, you can see that the communication is correct; in order to save the data to be processed later, a data reception system is developed.

D. Data Reception System

The data reception system is divided into three: Arduino, Python and Matlab:

1) *Arduino*: Arduino² is an open source electronic platform based on easy-to-use hardware and software. They have the ability to read analog and digital inputs. It can control the card what to do by sending a set of codes based on the programming language "Wiring" through a user interface based on "Processing".

This project is based on the Arduino one, which has 6 analog signal inputs, of which it uses 4 to read the data sent by the Myoware, the scheme of the implemented code can be seen in Fig. 6; in which you can see the Bluetooth connection, which is done through the serial port on pins 2 and 3 of the ATmega328P microcontroller which correspond to the reception and transmission of data respectively.

It sets a data transmission speed to 38400 baud which allows us to have an approximate sampling frequency of 333 Hz.

The sending of data and reading of the analog pins is done by means of the command "Serial.print (analogRead (A1))"; the data is sent by comma separating the values of each data channel, which are received in the same way by Python.

2) *Python*: Python³ is a programming language oriented to object, interpreted and interactive; combines remarkable efficiency with clear syntax. It has different modules, classes, exceptions, dynamic high-level data and dynamic writing.

In our case, it used Python as an extension language for Matlab, creating a layer code to provide Matlab with an easy way the data corresponding to the muscle signals obtained by the Myoware.

The code used in Python is graphed in Fig. 7; in the code the user enters the amount of data to be obtained in our case 3996 corresponding to approximately 12 seconds of sample at a frequency of 333Hz. You must verify in which serial port the bluetooth connection was made and configure the port in Python to be able to read data.

The data is saved in .txt format. A file is created and opened in which the received data is written line by line until the required amount of data is completed, after the file is saved;

This process must be repeated according to the number of samples required.

3) *Matlab*: Matlab⁴ is a software that combines a desktop environment for iterative analysis and design processes with a programming language that expresses matrix mathematics.

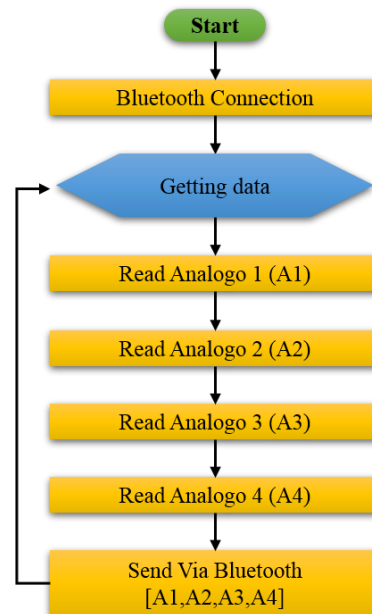


Fig. 6. Diagram of the Programming in the ATmega328p Microcontroller.

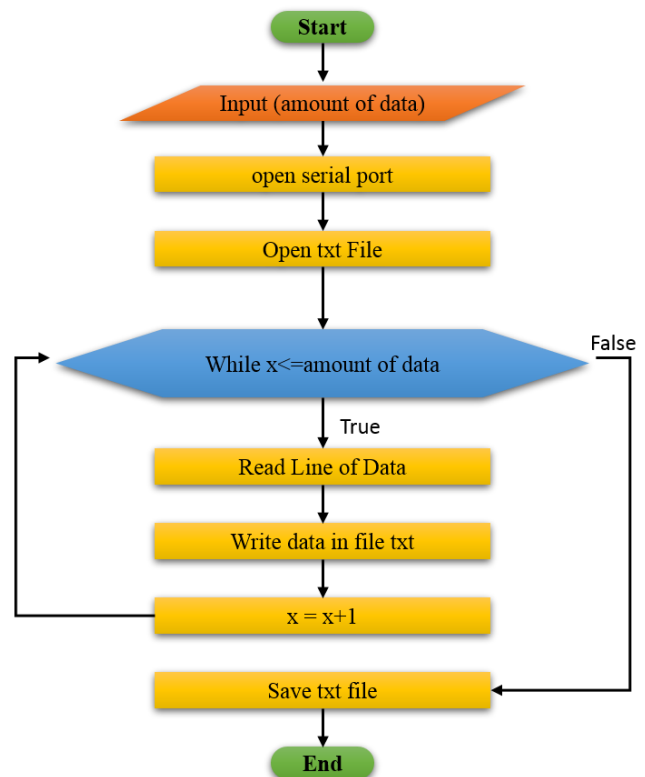


Fig. 7. Diagram of Programming in Python.

² Arduino, "Arduino." [Online]. Available: <https://www.arduino.cc/en/Guide/Introduction#>.

³ Python, "The Python Wiki." [Online]. Available: <https://wiki.python.org/moin/FrontPage>.

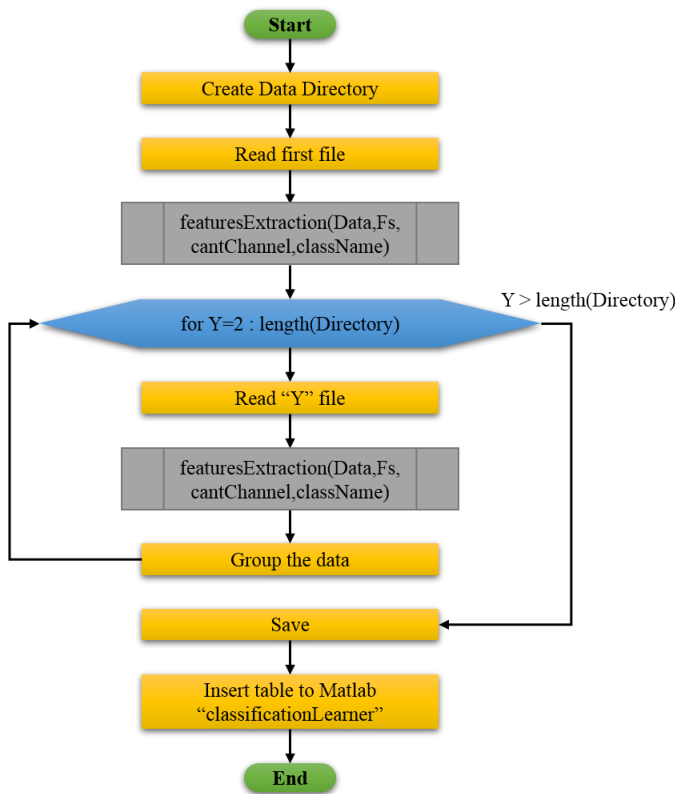


Fig. 8. Main Diagram of the Programming in Matlab.

It use Matlab to process and classify the data obtained using its Classification Learner application, it must extract the characteristics of the signals, for which we apply the algorithm of Fig. 8; which creates a directory with all the files generated by Python, reads the first file and extracts its characteristics, then enters a loop, which reads each of the available files, and then extracts the characteristics of the data, finally groups and save the results, which will be used for classification in the Classification Learner application, where you must manually enter the data table and choose the algorithm to classify.

There is a function (featuresExtraction) that extracts the characteristics, which has input parameters that are:

- Data: It is the data matrix read from the text files in our case is a matrix of 4x3996 data.
- Fs: It is the sampling frequency in our case 333Hz.
- cantChannel: It is the amount of data channels; our system is working with 4 data channels.
- className: Is the name of the class to which the data belongs, we will have 5 classes that correspond to the names of the fingers of the hand little finger, ring finger, middle finger, index finger and thumb in our case.

The mentioned parameters enter a function whose work diagram can be seen in Fig. 9.

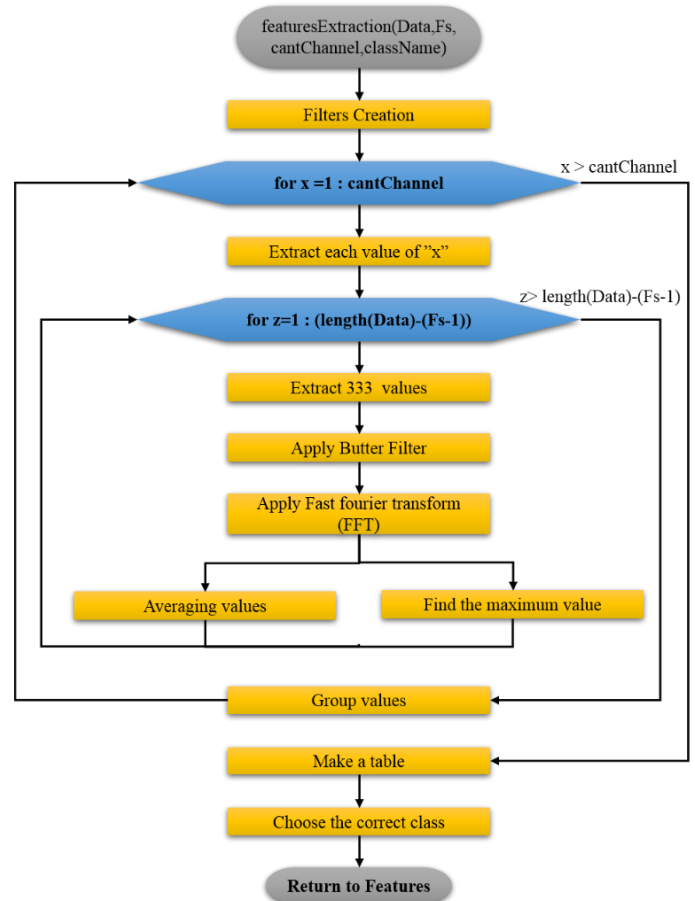


Fig. 9. Diagram of the Programming of the Features Extraction Function.

Taking into account that work will be carried out with amplitude signals between 0 to 10 mV and a frequency of 10 to 100Hz [2], [8], [9] and [10], the necessary filters are created for this purpose. Subsequently, each data channel is extracted, to then apply the filters and find the fast Fourier transform at intervals of 333 values which correspond to the sampling frequency, the intervals where it is applied are from the first data to the data 333, from the second data to 334, from third to 335, and so on, up to the full length of the data; then averaged and found the maximum value, thus obtaining the characteristics we need to classify, finally the values are grouped and converted to a data table by adding the class which they belong. With these operations, two feature vectors are generated for each channel.

III. RESULTS

The implementation of the system can be seen in Fig. 10(a), in which you can see all the connections made for its operation. In Fig. 10(b), the reader can see the placement of the system in the forearm from where it could obtain signals corresponding to the movement of the fingers of the hand.

In order to demonstrate the functioning of the system, samples of the movement of the fingers of the hand were taken, placing our development in the muscles of the forearm as in Fig. 10(b); samples are taken with an amount of data equivalent to 12 seconds with a sampling frequency of 333Hz;

⁴ "Matlab." [Online]. Available: <https://es.mathworks.com/products/matlab.html>.

sampling is done as follows: the first 3 seconds no movement is made after that, 6 seconds of movement in a finger is done applying force, finally the last 3 seconds no movement is made; It should be mentioned that samples are taken from a healthy person with a soft ball in the hand where the test is performed. A total of 71 samples are taken, which are processed according to the aforementioned algorithms and then classified.

In Fig. 11(a), the reader can see the signals obtained, following the aforementioned procedure. The thumb is corresponding to channels 1, 2, 3 and 4; in Fig. 11(b), the reader can observe the characteristics of the first channel; this type of signals is obtained for each data channel, which correspond to the peaks and averages respectively; in these signals, you can see that there are clear differences between one and the other, which will improve the efficiency of the classifier.

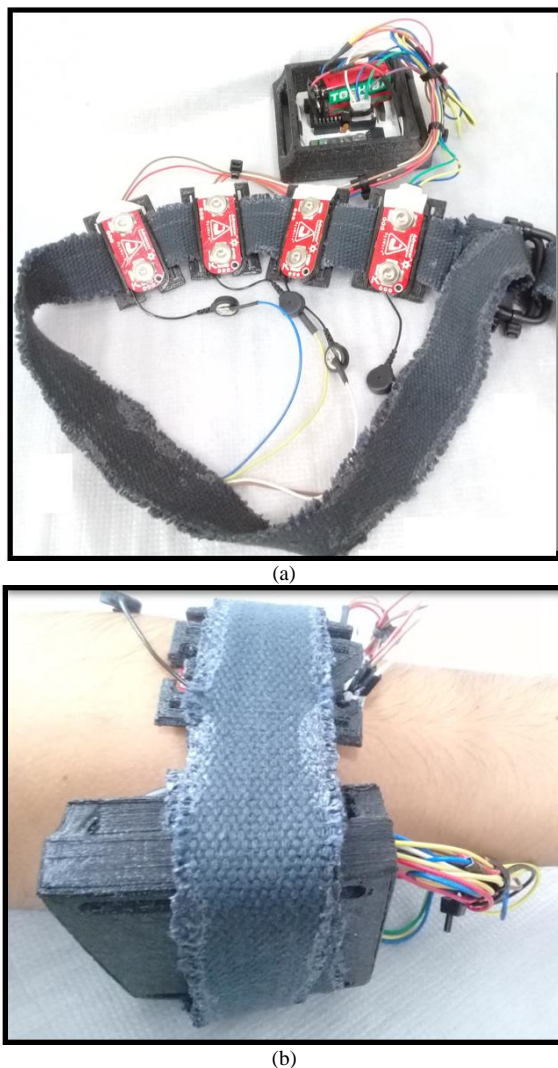


Fig. 10. (a) System Implemented.(b) Placement of the System in the Forearm.

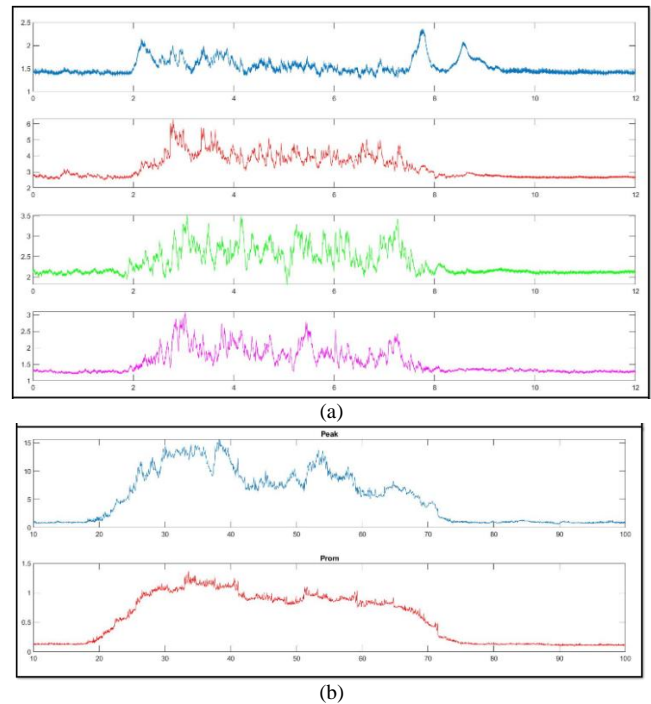


Fig. 11. (a) Raw Signals in Each Data Channel. (b) Signals of the Characteristics of the Channel 1 Data.

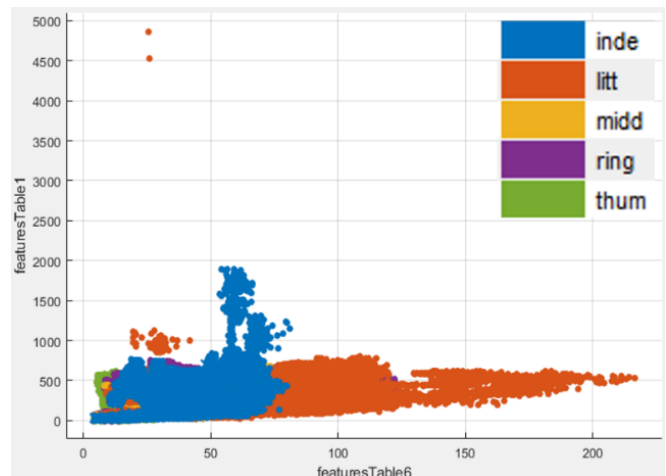


Fig. 12. Characteristics Plotted in the Classification Learner Application.

The characteristics obtained were introduced in the Classification Learner application, which can be seen in Fig. 12, which shows the graph of the characteristics of the 5 categories entered.

After entering the characteristics, the data classification algorithm is chosen, in our case, it chooses k-Nearest Neighbors (KNN) which generates a certain rate of 99.1% and also generates a confusion matrix, which the reader can see in the Fig. 13, which the performance of the chosen algorithm is evaluated.

True class	Predicted class				
	inde	litt	midd	ring	thum
inde	54213	28	346	55	318
litt	24	51143	39	54	36
midd	329	18	50686	81	182
ring	57	54	78	54719	52
thum	355	49	145	46	47037

Fig. 13. Confusion Matrix Generated by the Classification Learner Application.

IV. DISCUSSION

In the research work [2], it used 8 data channels and got an efficiency of 80%. In the research work [6], it used 5 data channels, and a variable efficiency was obtained between 57.69% and 99.92%. In [11], the average efficiency of 54% was achieved by testing multiple configurations of samples and data processing. In [12] the error rate is 7% by classifying 14 kinds of finger signals. In [13] an average efficiency of 70% was obtained, making the classification of 52 classes of movements with different classification algorithms. In [14], the effectiveness of 60% was obtained for the creation of a database, testing different classifiers.

V. CONCLUSIONS

In conclusion, the classification of EMG signals has been achieved. On this work, with 4 data channels have reached a percentage of correct answers of 99.1%, which shows that our system is reliable and optimal for obtaining EMG signal data in future jobs.

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