Signal and biosignal acquisition system for teaching in education: conditioning and analysis methods with embedded devices

Sistema de adquisición de señales y bioseñales para la enseñanza en educación superior: métodos de acondicionamiento y análisis mediante dispositivos embebidos

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DOI: 10.35429/JTAE.2022.15.6.16.23 Received: January 20, 2022; Accepted: June 30, 2022

Abstract

The use of signals of different types in engineering is important since technological development is based on the knowledge and treatment of these, such as EMG and ECG biopotentials in biomedicine or fuel mixture and air flow signals in the automotive industry. The objectives of these projects are to offer an integrated signal acquisition and visualization system that serves as a basis for the learning of higher education students in areas such as biomedical and automotive. Designing a low-cost digital system programmed in an embedded system with sensors and visualization software. This contributes to the development of students in the treatment of signals in different areas, signals such as biological and automotive

Biomedicine, Acquisition, Embedded systems

Resumen

El uso de las señales de diferentes tipos en la ingeniería es importante ya que del conocimiento y tratamiento de estas se basa el desarrollo tecnológico como por ejemplo los biopotenciales EMG y ECG en biomédica o las señales mezcla de combustible y flujo de aire en automotriz. Los objetivos de este proyecto es ofrecer un sistema integrado de adquisición y visualización de señales que sirva como base para el aprendizaje de alumnos de educación superior en áreas como biomédica y automotriz. Diseñando un sistema digital de bajo costo programado en un sistema embebido con sensores y software de visualización. Contribuyendo así con el desarrollo de los alumnos en el tratamiento de señales en diferentes áreas, señales como las biológicas y las automotrices

Biomedicina, Adquisición y Sistemas embebidos

Citation: SAMANO-FLORES, Yosafat Jetsemani, SERRANO-RAMIREZ, Tomás, LOPEZ-RODRIGUEZ, Pedro and MANDUJANO-NAVA, Arturo. Digital competences in distance education for high school education systems. Signal and biosignal acquisition system for teaching in education: conditioning and analysis methods with embedded devices. Journal of Technology and Education. 2022. 6-15:16-23.

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June 2022, Vol.6 No.15 16-23

Introduction

In history of México the education always suffering due to low investment in the sector. This has caused an important gap in the teaching levels. Is a problem that affect to student life of people.

One of the most affected levels is higher education due to this level is the transition of the student between their education and their insertion into working life. The students have problems when they want to apply their abilities in their jobs because they have never had the necessary equipment and tools for their preparation.

Most of the universities don't have the minimum infrastructure, laboratories, equipment and space for the correct education. Because the students can't adapt to their working life and the reason was, they didn't acquire the practice knowledge necessary to the work.

Another reason is the little percentage of university engineering graduated students and the Mexican development of technology is deficient. The national engineers don't have the necessary skills to afront world challenges.

Because of that is necessarily have versatile and low-cost tools that give the student the enough and basic knowledge to their career application.

For above we generate a system capable of acquire a preprocessing signal and biosignals for the different areas of engineering. The signals in the engineering are very important because are the parameter with the technology interacts with the environment.

All kind of signals are a familiar parameter for the academic sector, especially in engineering.

Engineering area	Signal type
Biomedical	ECG, EMG and EEG
Automotive	Gas mixture and oxygen
Electronic	Ultrasonic and Optics
Mechanical	Movements

Table 1 Signal types

Are needed systems for acquire and provide this signals types to the engineering students, the signals are saved and then used for control and processing applications. These signals can be showed and used in their treatment for specific areas.

The technologies developed in this work proposes the use of integrate embedded devices that provide the possibility to interacting, processing and analysis the signals.

The system in this work is a system that incorporate several electric ang biological sensors which are connected to a FPGA, the system made a signal ang conditioning signals for student work. These signals are showed in MATLAB where the students can do a processing with specific objective.

The system offers the signals for engineering work. Is needed offer to the market more efficient and accessible devices that motivated it use and have a better work culture

State of the art

More complicate signals are the biological ones because it is the signal with less amplitude and that made not any sensor or device can detect it. Because of that. the system in the first stage work for EMC, ECG and EEG acquisition. Subsequently we will work with automotive signals only changing the acquisition sensor.

Next only showed the estate of art for biosignals because we work with the most complicate acquisition and that is the biological acquisition, this will replicate in mechanical, electric and all kind of signals.

In the figures 1, 2 and 3 are showed the most used acquisition arrays for sEMG Signals. Output of these array can use for a biomedical amount applications like medical valuations, processing to diagnosis, and prothesis control [1] [2].

ISSN 2523-0360

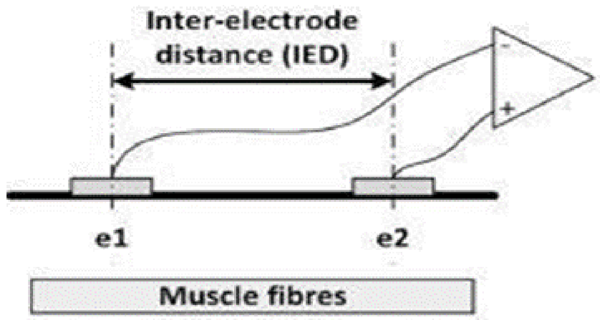


Figure 1 General acquisition array sEMG

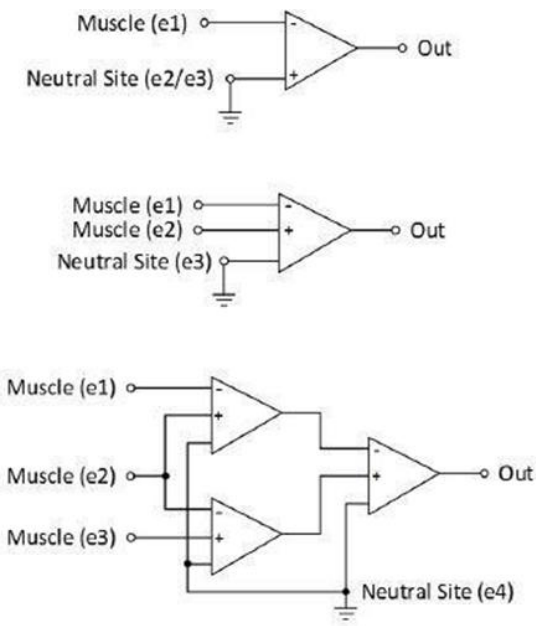


Figure 2 General acquisition sEMG several derivations

One-line biosignal acquisition

This system shows only one biosignal, using a sensor, embedded device and visualization software.

Used method is a 2D electrode matrix band based and conditioning in Bandmyo system

A Dell OptiPlex server was developed (Intel Xeon E5-2640 / 64-GB RAM / Tesla K80 Black GPU with 24 GB of GDDR5 and MATLAB R2016A and Phython 3.5.2 processing software, responsible for processing information through a deep learning method and neural networks, the sEMG signal is broken down, segmented, and with this, images of muscle activation are generated, which serve as input to the neural network with the aim of recognizing gestures in the corresponding software [4].

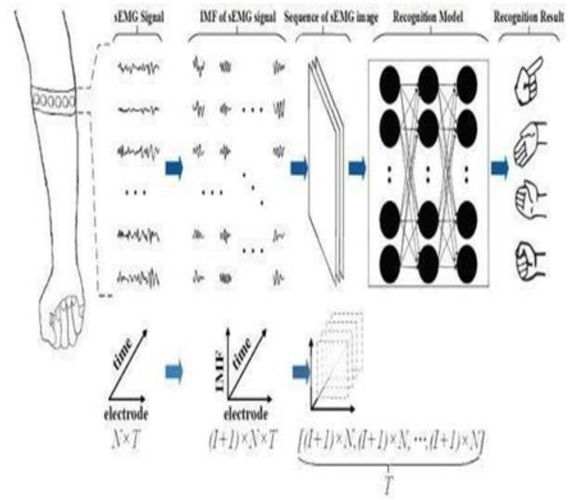


Figure 3 Gesture recognition through Bandmyo

This system shows the visualization in intelligent device that makes the system more versatile for the applications as shown in Figure 4 [6].

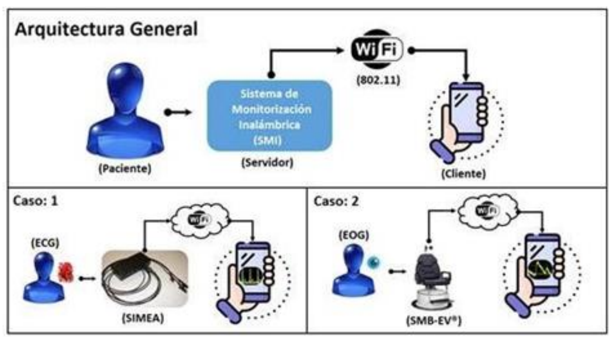


Figure 4 Visualización inalámbrica de biopotenciales

The above projected in used applications can serve to detect or alarm the state of the human body as shown in Figure 5 [7].

Figure 5 Detection of stress in the human body based on biopotentials

Several lines biosignals acquisition

This system shows the several biosignals acquisition using a sensor, embedded device and display software. ECC-PDMS electrodes were used in a 4X1 surface matrix and conditioned with a 50Hz notch filter and 30-20 Hz bandpass, the main objective of the system shown in Figure 2.6 is sEMG classification using RMS, LABVIEW and sEMG visualization [5].

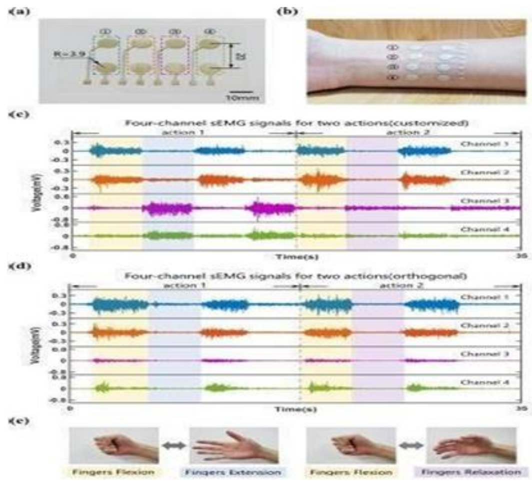


Figure 6 Electrodes, sEMG and gesture

Larger or different arrays can be positioned somewhere on the body to get more information

In the system shown in Figure 7, a multichannel array of 64 electrodes is applied in a grid. And it is filtered with amplifiers and a bandpass filter.

The objective of the research is to generate activation images of muscle areas that are then spatially filtered for feature extraction using MATLAB processing software [3].

The result are images in MATLAB and their feature extraction with spatial filters [3].

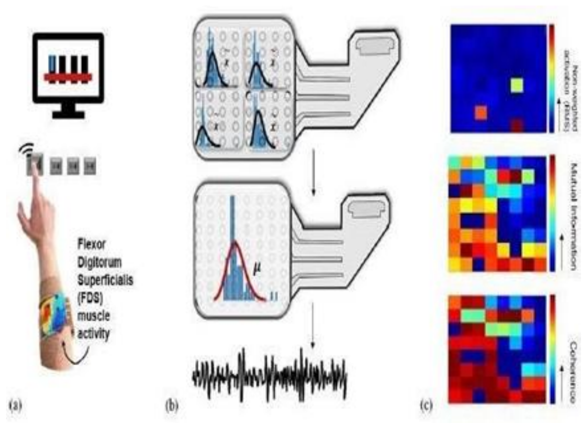


Figure 7 Noise reduction through spatial filtering

State of art analysis

Figure 8 shows a diagram that compiles the information on the state of the art in recent years where we can see that the systems have certain trends in two parameters, the acquisition arrangement and the processing hardware and software, their applications too.

These trends mark common factors in the arrangements and devices that are used to carry out the stated objectives and oriented to applications mainly of statistics, control and pattern recognition.

The systems in their acquisition stage makes their efforts to the measurement of certain parts of the body, the most common and which the measurement can be better considered.

In the conditioning stage, the instrumentation amplifiers of different gains and most of the systems converge in the development of filters for noise elimination and bandpass filters.

In the processing stage, there is more incidence in the microcontrollers regarding the hardware and the MATLAB platform regarding the software.

This diagram is an x-ray or an overview of the paths and directions of signal processor research and clarifies the horizon for the development of new applications as shown in Figure 8.

Although there are acquisition and visualization systems in different areas, very few of them are oriented towards education.

All the benefits shown in Figure 8 will be applied in the teaching of students with this project.

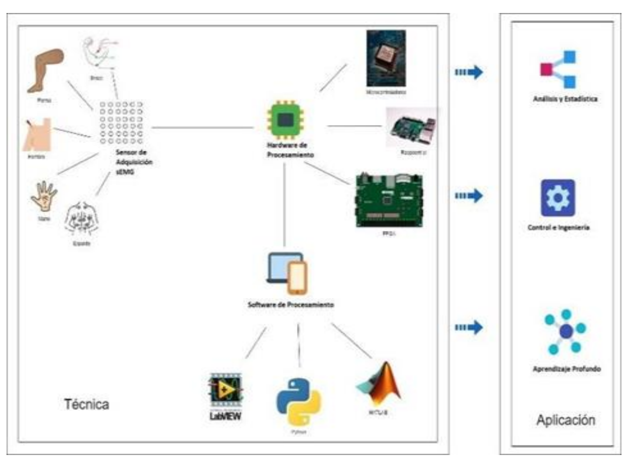


Figure 8 State of art analysis

System development

A system with 3 fundamental parts is proposed. Sensors, development board and visualization as shown in Figure 9.

ISSN 2523-0360

The objective is a system that collects information in the form of signals from the environment where it is working through different types of sensors, this information goes to preprocessing through in the FPGA and deliver to the student preprocessed signals and visualized in MATLAB so that they can work with them.

The process and implementation of hardware, acquisition of signals, processing and visualization is shown in the block diagram of Figure 9.

Figure 9 Project Block diagram

The communication interface between sensor and FPGA, FPGA y MATLAB is showed in Figure 10. Is used Arduino as a digital analog converter with 10-bit resolution.

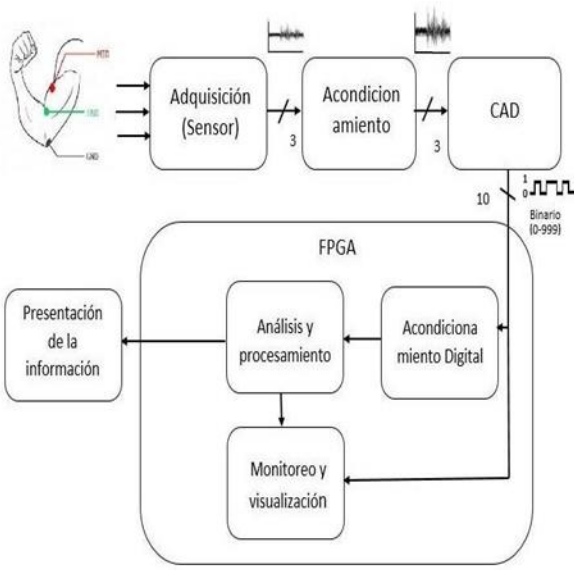


Figure 10 Interface and communication block diagram

The physic implementation of proposed system is showed in Figure 12 and 13. The signal sEMG of biceps in this case is acquire by sensor and electrodes, then is communicated with an analog digital converter and then transferred to FPGA as shown in Figure 13. In FPGA showed in Figure 12 is digitally incorporate a decimal data 0 -999 because of the resolution converter, this data is showed too in the FPGA displays.

This signal is mapped and adapted to a 0-3.9 voltage level, that corresponding to a power source of FPGA.

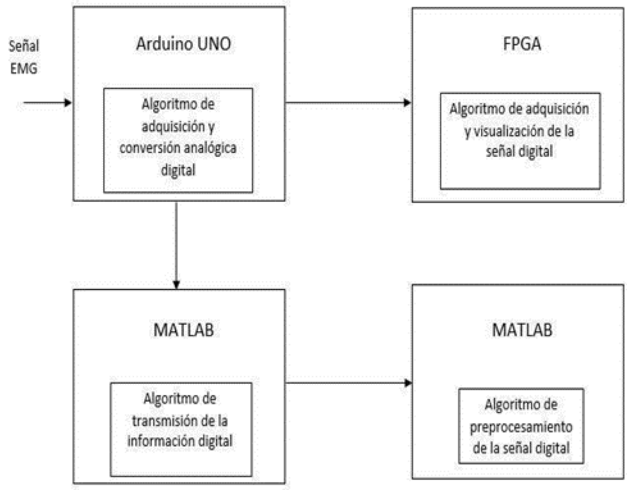


Figure 11 FPGA Xilinx Nexys 4

The diagram is visualized in Figures 12 and 13. The digital signal is transferred to computer where is made a preprocessing with MATLAB software and showed in MATLAB plotter.

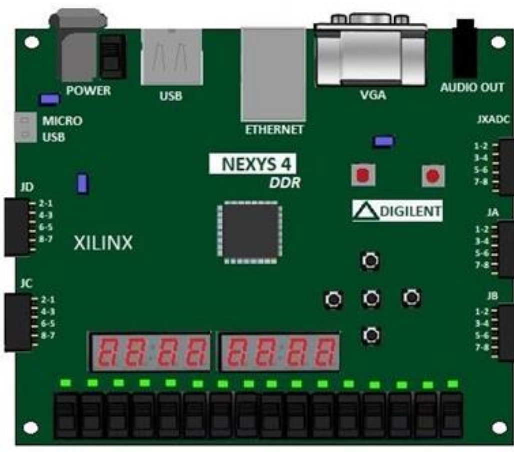


Figure 12 Schematic prototype of system

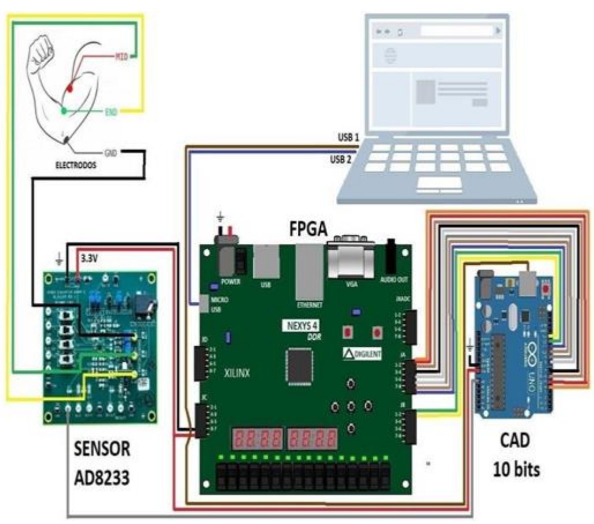


Figure 13 Signal connection

Results

We can visualize signal or data provide to students in 3 different stages. The first stage in analog sensor output through oscilloscope for the student can visualize the original signal as showed in Figures 14, 15, 16 and 17, this signal is acquired with the biopotential sensor.

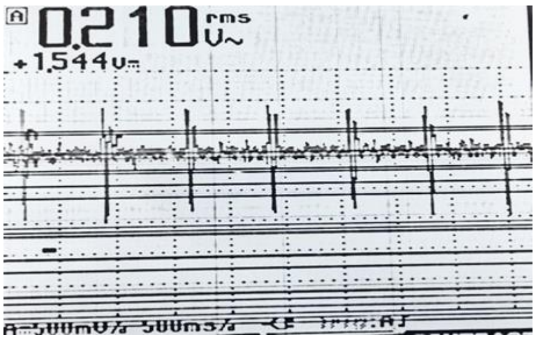


Figure 14 Analog signal ECG acquire with sensor

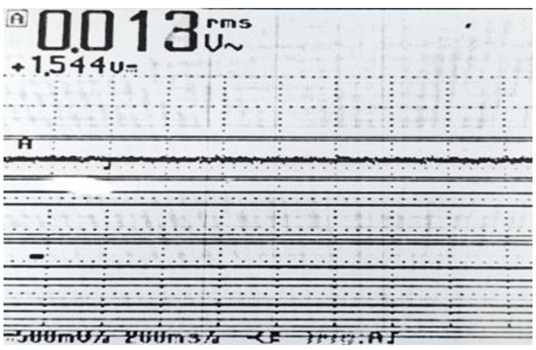


Figure 15 Relax analog signal ECG acquire with sensor

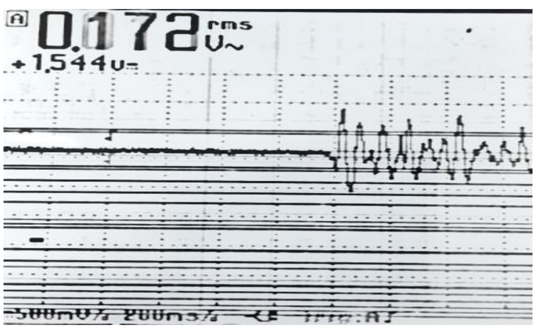


Figure 16 Relax-strength analog signal ECG acquire with sensor

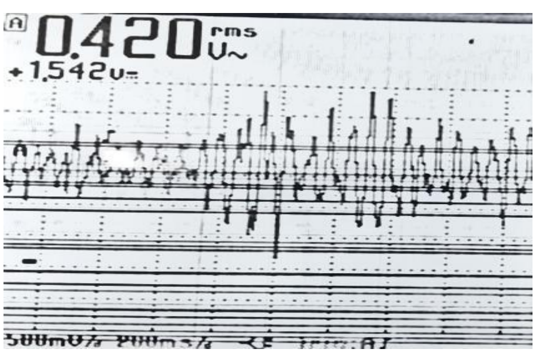


Figure 17 Strength analog signal ECG acquire with sensor

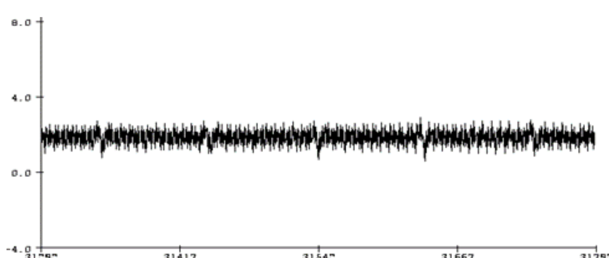
In the second stage can visualize as a numeric data in 3 digits as shown in the FPGA displays as shown in Figure 18 and 19. The numeric data is 0-999 range. This range is because the 10-bit converter resolution. This data is useful for all statistics problems and mathematics equations for analysis.

Figure 18 FPGA digital display

Figure 19 Numeric data display

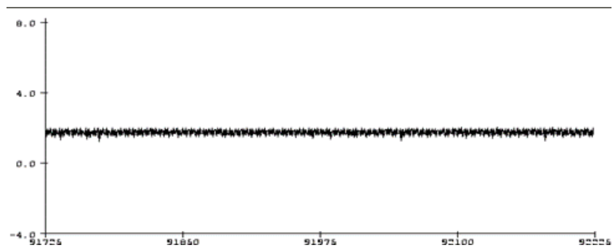
In the final stage the software MATLAB provide images that the student can visualize as shown in Figures 9, 10, 11 and 12 where is delivered a preprocessed signal ready to the specific work in every engineering area.

These signals are showed in Arduino plotter too, is an option for reduce the cost of the system and the student can visualize a preprocessed signal too as shown in Graphics 14, 15 and 16. The first data and signal acquisition and transfer results are show in MATLAB and the FPGA in Figures 5.5, 5.6 and Graphics 5.4, 5.5 and 5.6.

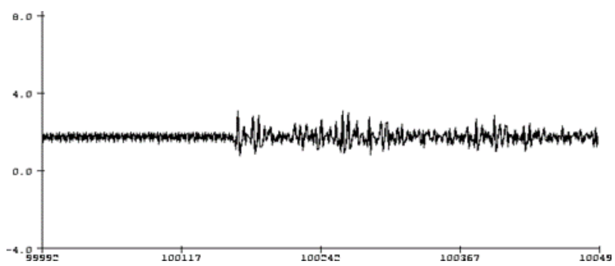


Graphic 1 Arduino ECG digital signal

ISSN 2523-0360

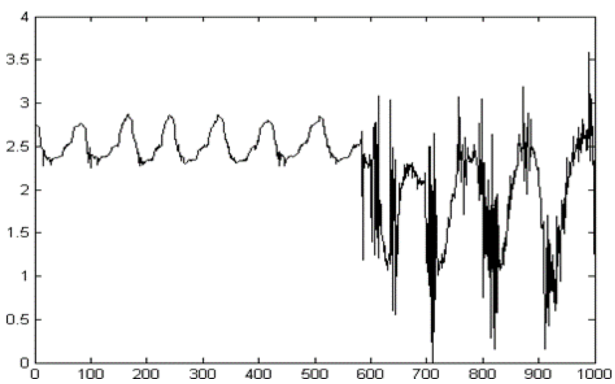


Graphic 2 Arduino EMG digital signal (relax)

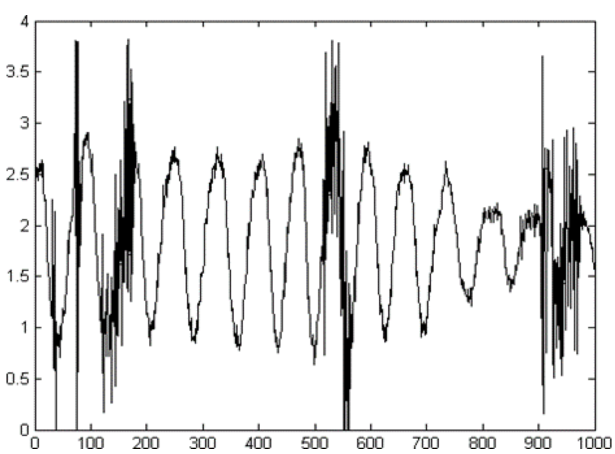


Graphic 3 Arduino EMG digital signal (strength)

The Graphics 4, 5, 6 and 7 was obtained in a relax-strength bicep routine, the part highlighted in black represents the muscular effort and its duration.



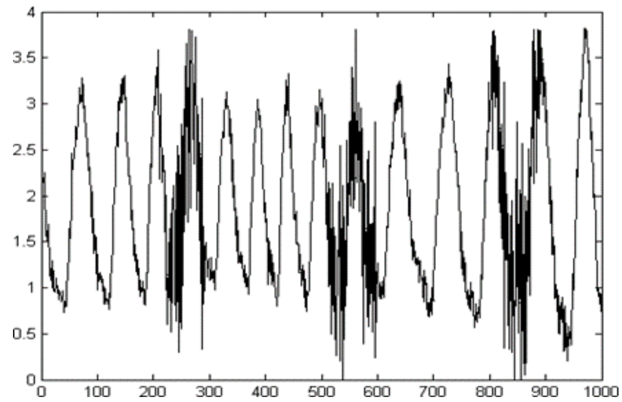
Graphic 4 MATLAB digital signal 1



Graphic 5 MATLAB digital signal 2

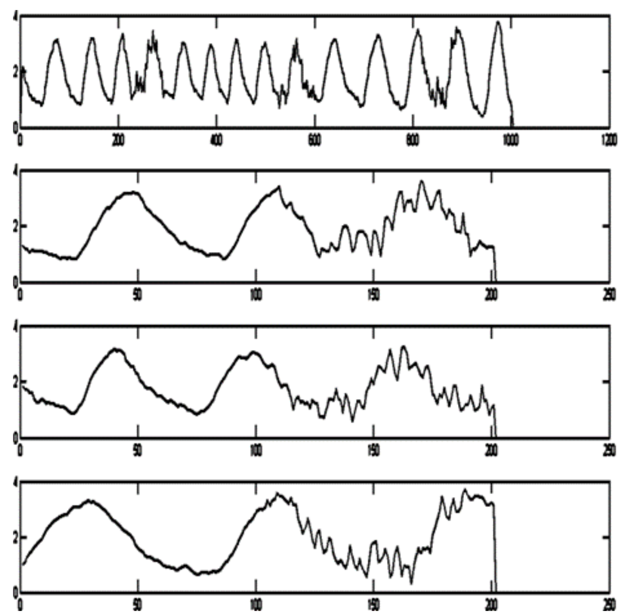
MATLAB generates a vector where sabe 100 samples of sEMG signal as shown in Graphics 5, 6 and 7.

In the image showed in Graphic 6 is show a movement routine where the muscle made a relax-strength routine in three times, this movements was realized between 100-300, 400-600 and 700-800 samples, the highlighted port of the signa represent the flexing of muscle.



Graphic 6 MATLAB digital signal 3

Later they were extracted the signals segments where the muscle realizes the strength, in these segmented signals was apply a media filter od 3 samples and the results as shown in Graphic 7.



Graphic 7 Preprocessed, segment and compare EMG digital signal in MATLAB

We can note how signal get better in amplitude with the filter and you can better appreciate the change in EMG due to muscle effort as shown in Graphic 7. The signal and vector characteristics are saved and can be configurated in basis of the specific need in the several engineering areas and depends of every signature.

Conclusions

This project offers a good number of tools (Sensors, Arduino, FPGA, Arduino viewer and MATLAB) that the student can use to generate their own knowledge and thus achieve the objective of the subjects they are studying.

The use of versatile and easily accessible platforms such as the one presented in this project brings the student closer to the application of their knowledge in the areas for which they are preparing.

This system reduces the deficiency gap caused by the lack of equipment for practical applications and strengthens students' abilities Universities will have easier access to specialized equipment because this type of platform is low cost. It is imperative that these types of technologies become more common because in modern time access to specialized equipment increasingly will be harder every time.

Financing

The authors don’t receive financing for develop of this research.

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