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Manipulation of Robotic Arm with EEG Signal

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Abstract: This project has as objective identify some facial expressions using the sensor "Emotiv EEG neuroset". This device is a sensor capable of receive and interpret the bioelectrical activity of the brain, through Electroencephalography technique (EEG) besides has 16 channels with continuous accurate reception of brainwaves. In addition, the sensor has a SDK easy to use allowing that anyone person can handle it even without any experience in brain signals acquisition. The Emotiv® data were transferred to MATLAB® for filtering the brainwaves in order to send the information through serial communication to Arduino. Obtaining as a result an identification of three different expressions as wink, blink and smile, each expression has a different LED color in the Arduino board.

Key words: Emotiv, EEG, BCI, facial expressions, Arduino, LED

INTRODUCTION

This project is based on the use of the Emotiv device with wireless headphones and portables electrodes for brain signals acquisition and their interpretation in a BCI platform, allowing an easy to understanding to user (Anonymous, 2015a, b). The Emotiv transmits the brain signals wirelessly to an interface that can recognize three types of commands in real time, the firstly are facial expressions using the expressiv module, secondly are emotions using the affectiv module and thirdly cognitive activities using the cognitiv module (Duvinage *et al*., 2013).

This sensor is based on the Encephalography (EEG) with their 16 electrodes located in the defined form by the international standard 10-20. The standard distances between each electrode must be between 10 and 20% of the bilateral total distance of the skull. This standard allows the correct register of electrical potentials generated inside of the brain cortex and in this way send this information to Brain Computer Interfaces (BCI) (Kanas *et al*., 2014). The BCI facilitates the control of devices through the signals classification given by the brain human (Wolpaw *et al*., 2002).

Another system commonly used as a brain signals acquisition device is the NeuroSky EGG (Anonymous, 2014) which allows scanning and amplifying the analogical signals of the brain to serve as input for other devices. As a difference between Emotiv and the NeuroSky is that the NeuroSky focusing in the user characteristics such as attention, concentration, memory, mental acuity, meditation and relaxation. In order to observe each facial expression through LED an embedded system called arduino and free software were used to communicate the computer with the user.

Previous experiences: The Emotiv device has allowed the progress and development of control technology through brain signals in many applications fields such as medicine, communication devices, etc.

Example of the previous information is when the Emotiv was used as gatherer of signals from patients with normal and low hearing (Badcock *et al*., 2015). This register was made in patients with old age with the purpose of identifying different patterns of this disease in patients with age between 6 and 12 years old. Using expressions and emotions reach in the EU move a manipulator of seven freedom degrees, the movements applied were open and close gripper up and down the arm and left and right rotation (Ouyang *et al*., 2013).

An experiment made in 2010 with a phone platform controlled by the Emotiv sensor with the purpose of control some phone activities with facial expressions, thoughts or emotions such as call to a specific contact (Mukerjee, 2010). This way was proved that Emotiv is a system of good recognition of neural wave with a low cost.

Colchester UK made a surprising advance using Emotiv in the science and medicine field, they reached controlling of an electric wheelchair with a facial

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expression to move it and a head move to stop the chair (Rechy-Ramirez and Hu, 2013). The user has the total control of the chair and can choose between 5 facial expressions and 3 head movements for using in each movements of the chair. This project is a huge advance for quadriplegic people or with some type of paralysis in their body because allow a free movement with a minimum effort.

On the other hand, developments in Arduino have been entertainment purposes as the control of LED or lights for a party (You *et al*., 2014). Besides, using the Kinect to identify the facial expressions in people for interpreting their emotions and manage the light in the party according with the feelings of people on it.

Other relevant project using of arduino is for processing and acquisition of digital sound as well for producing of digital sound for example the piano emulation in cell phones (Silva *et al*., 2015).

EEG signals: A EEG device makes the measurement of electrical signals produced by neurons when they communicate each other (ionic current) and this is the way to measure the brain activity conciencia (Anonymous, 2015a, b). This measured has different frequency and amplitude depending of conscious level of the patient. For example, when a patient is sleeping the frequency of the signal, changes according with the types of dreams.

The brain cells are called neurons, these have a different development than other cells in the body, these have the ability of communicating each other in a process called synapsis. There are two types of synapses, firstly chemical synapsis where the information is transmitting through neurotransmitter and show high plasticity (Cebollero, 2011). This means that the neurons are more active and transmit with major facility.

Secondly, is the electric synapsis where the information is transmitted through the transfer of ions and in this way is produced the movement of ion loads that generated small electrical impulses and adding of these impulses is know as electric potential. In addition, these electric potentials are detected by the EEG device.

For acquiring these electric potentials, the Emotiv has a distribution of electrodes according with the international standard 10-20. Emotiv has electrodes in different brain areas such as Frontal (F), Center (C), Parietal (P), Occipital (O), Temporal (T), Frontal polar (Fp), between Fp and F (AF) and between F and C (FC). This distribution of electrodes is shown in Fig. 1.

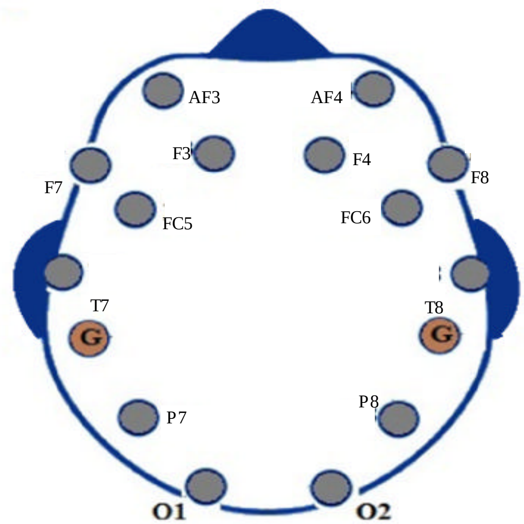

Fig. 1: Electrodes distribution of Emotiv

MATERIALS AND METHODS

For the realization of this project, it was posed the next methodology with activities related to the development of the general objective (Fig. 2).

Equipment selection: The equipment selection was made according to the necessities of the project:

- Embedded system: Arduino
- Motor: servo motor
- Driver: Tarjeta Mx-32
- Software: MATLAB
- Wireless communication: Bluetooth

Analysis of EEG signal according to facial gesture: The analysis in MATLAB was realized with different libraries which was implemented for handling of the different commands used by the sensor. In this case, it used the Emotiv library and it was established a process to recognize the different facial expressions Fig. 3.

In order to acquire the brain signals for the patients, the Emotiv sensor was used. Each patient took various tests for each facial expression, determining that the smile, blink and wink are highlighted from the other signals. These facial expressions are related to the sensors F8, F7 and AF3 as shown in Fig. 2.

For interpretation the brain signal, MATLAB with the expressiv library was used. The signals were analyzed and classified the peaks of each facial expression signal. After this was organized the data in order to send the information to arduino and turn on or turn off the corresponding LED.

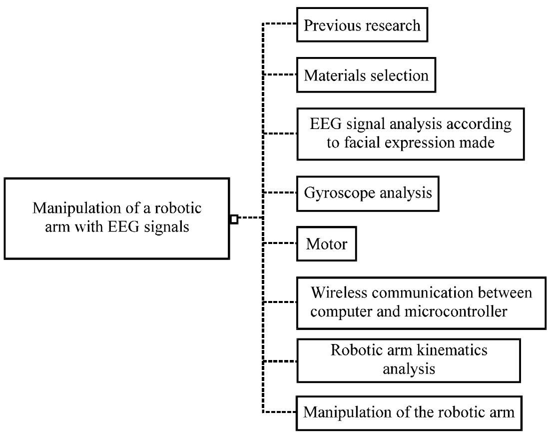

Fig. 2: Methodology

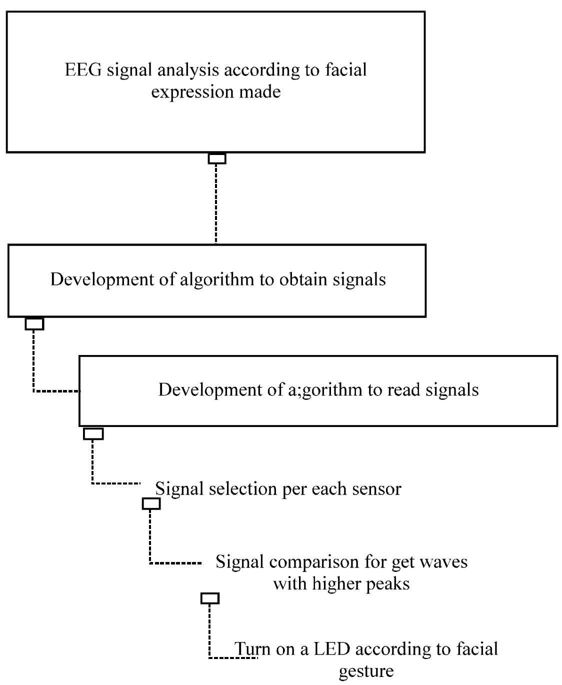

Fig. 3: Methodology to acquiring signals, according to facial expressions

To obtain and read the EEG signals generated by Emotiv, it was implemented the next MATLAB process (Fig. 4).

Analysis of gyroscope signal: The gyroscope was used to perform the rotation of each degree of the manipulator, after that it was realized the analysis of the signals and it implemented an algorithm for sending the relevant commands to embedded system (Fig. 5 and 6). To analyze the signal generated by gyroscope was implemented the next process in MATLAB.

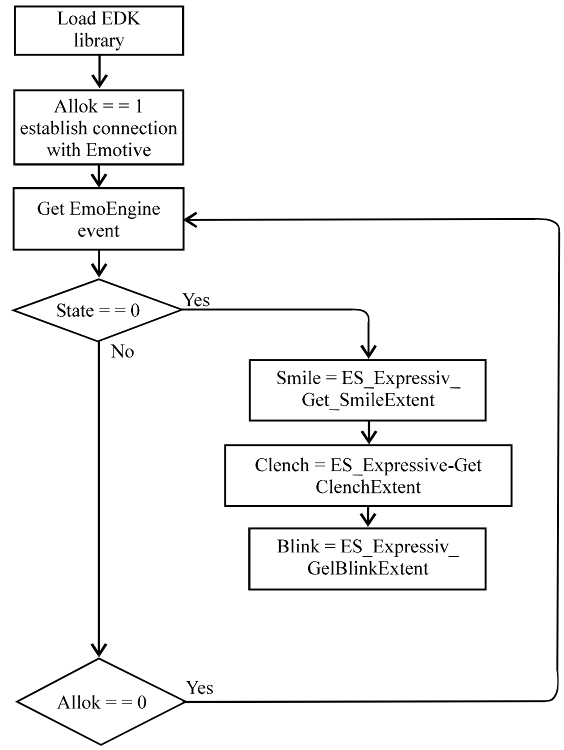

Fig. 4: Process for acquiring and reading EEG signals

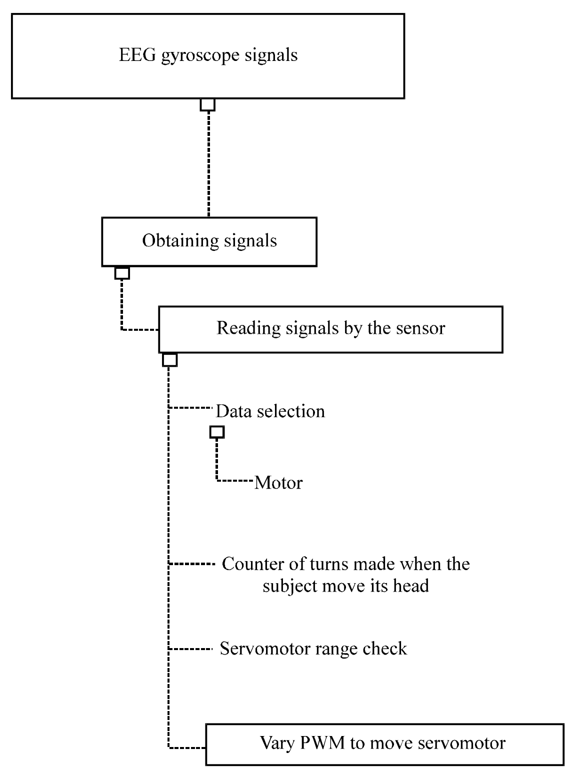

Fig. 5: Process for acquiring and reading gyroscope signals

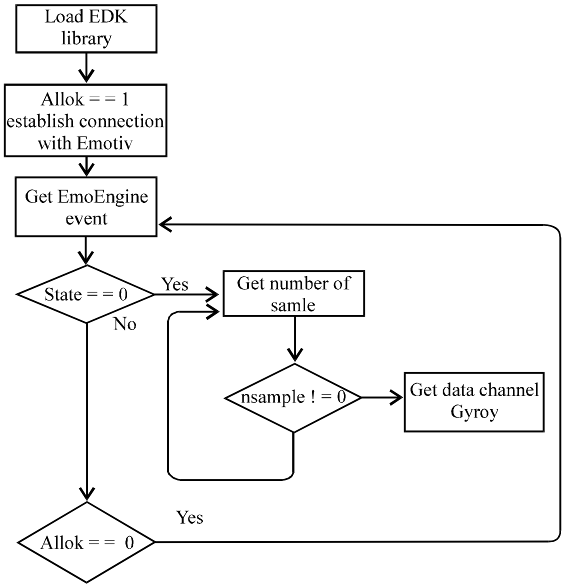

Fig. 6: MATLAB algorithm for processing of gyroscope signals

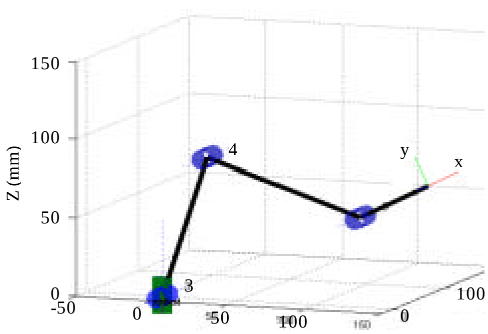

Fig. 7: Simplified representation of the robot manipulator

Table 1: Denavit-hartenberg representation

ART	θi	Di	Ai	αi
1	1	0	0	0
2	2	0	La	-π/2
3	3	0	Lb	0
4	4	0	Lc	0

Direct robot kinematic: To determinate position and orientation of end effector with regard to the fixed coordinate system located at the base it has been made the kinematic analysis Fig. 7. Through the Denavit-Hartenberg convention, it stablished the reference system to find out the transformation matrix T (Table 1):

$$T = {}^{0}A_{4} = {}^{0}A_{1} * {}^{1}A_{2} {}^{2*}A_{3} * {}^{3}A_{4} \tag{1}$$

With the table values, it proceeded to find the matrix value for each joint A^1_0, A^2_1, A^3_2, A^4_3 and then it can find the final position in regard to origin:

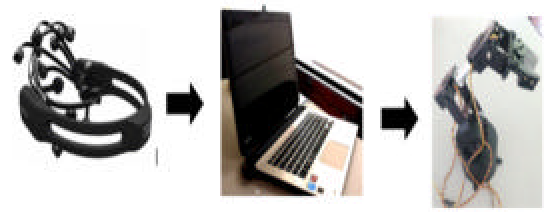

Fig. 8: Implemented hardware on the project

$$A_0^1 = \begin{bmatrix} c\Theta_1 & 0 & -s\Theta_1 & 0 \\ -s\Theta_1 & 0 & c\Theta_1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

$$A_1^2 = \begin{bmatrix} c\Theta_2 & -s\Theta_2 & 0 & la*c\Theta_2 \\ -s\Theta_2 & c\Theta_2 & 0 & la*c\Theta_2 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

$$A_2^3 = \begin{bmatrix} c\Theta_3 & -s\Theta_3 & 0 & lb*c\Theta_3 \\ -s\Theta_3 & c\Theta_3 & 0 & lb*c\Theta_3 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4}$$

$$A_3^4 = \begin{bmatrix} c\Theta_4 & -s\Theta_4 & 0 & lc*c\Theta_4 \\ -s\Theta_4 & c\Theta_4 & 0 & lc*c\Theta_4 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{5}$$

The end effector position will be designated by:

$$A_0^4 = A_1^2 * A_1^2 * A_2^3 * A_3^4 \tag{6}$$

This project used the Emotiv sensor as a tool to acquire the brain signals. One laptop for processing, classifying and filtering the signals. Finally, one arduino board to show the recognition of the brain signals, this elements are shown in Fig. 8.

Robotic arm manipulation: To can manipulate the robotic arm, it analyzed and classified the received signals, according to the wave peaks showed by every gesture and it was became in logical data and send to the microcontroller. This data was transmitted from MATLAB to microcontroller, so that, later it had been used to move the manipulator robot servomotor, how it shows at Fig. 9 and 10.

For the implementation of the signal measured with Emotiv EPOC and captured through an interface made in MATLAB it has been used a microcontroller which allowed the handling of servo motors incorporated in the robotic manipulator of 4 DOF.

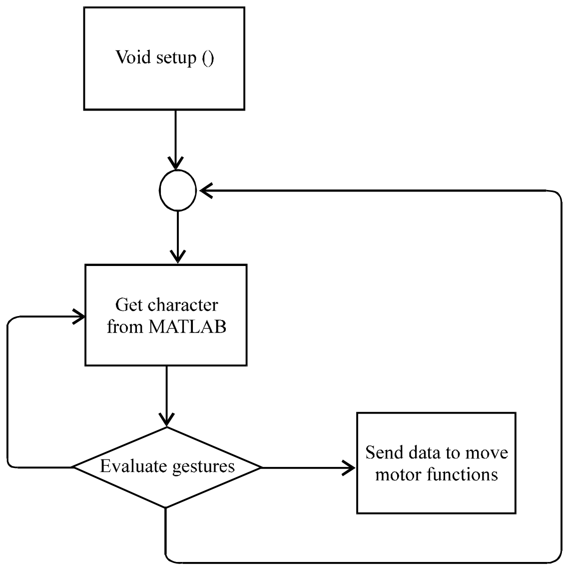

Fig. 9: Microcontroller process

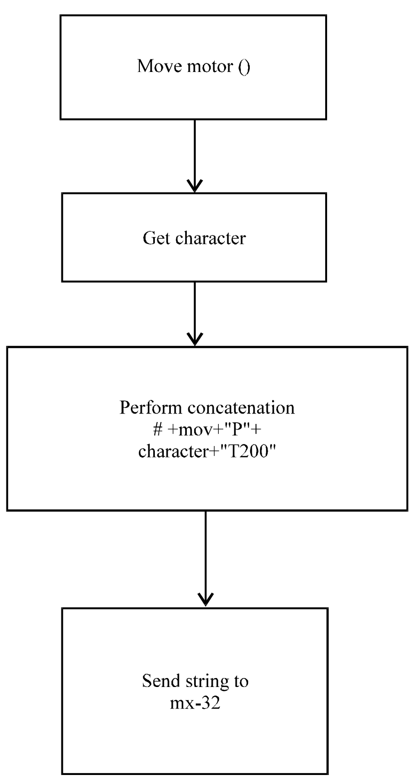

Fig. 10: Process to move motors

This project includes Emotiv as a tool of signal acquisition, the computer as control station and the microcontroller as output system for the conditioning and control of manipulator's motors.

The virtual platform of Emotiv showed different results for each express ion which were acquire and associated to the different variables for have control over the data from the MATLAB interface and the wireless connection with Emotiv.

RESULTS AND DISCUSSION

Using the Emotiv EEG was possible making the measure of each electrode corresponding to each facial expression. According to the signal got from the AF3 electrode when the patient blinks was generated a peak of 230 μV as is shown in Fig. 11.

The signal generated by F7 electrode was associated to the wink of the patient and had a peak of 120 μV as is shown in Fig. 12. The signal of a sequence of four winks presented an average value of 90 μV and error of 7.2% as is shown in Fig. 13. The signal captured by F8 electrode correspond to the patient's smile and presented a peak of 190 μV as is shown in Fig. 14.

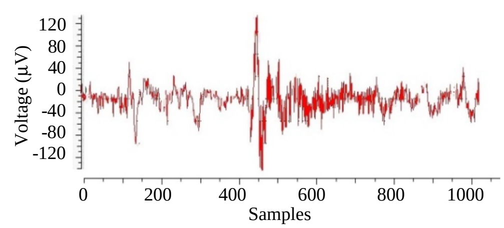

Fig. 11: The signal of blinking from the AF3 electrode

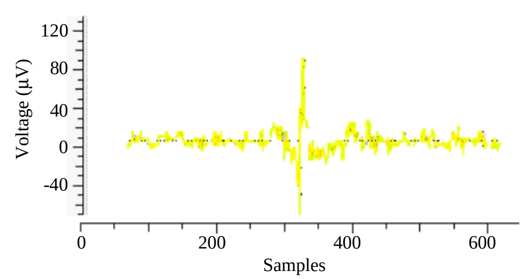

Fig. 12: The signal of winking from F7 electrode

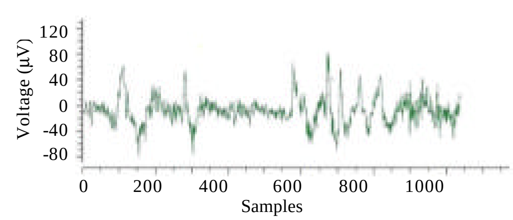

Fig. 13: Signal of four winks captured by F7 electrode

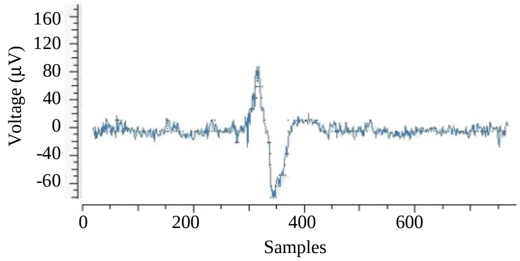

Fig. 14: The signal of smiling captured by F8 electrode

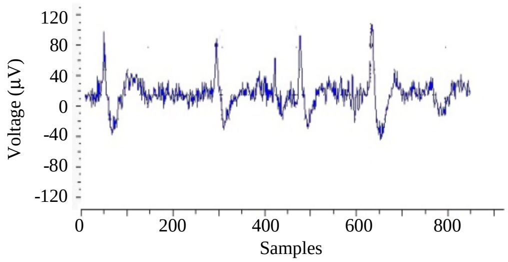

Fig. 15: Signal of two smiles captured by F8 electrode

Table 2: Number of success attempts for each facial expression

Subjects	Facial expression					
	Blinking		Winking		Smiling	
	Success	Attempt	Success	Attempt	Success	Attempt
1	12	12	10	11	12	12
2	10	12	11	11	10	12
3	11	12	8	11	12	12

Table 3: Percentage of success for each facial expression

Subjects	Percentage of success		
	Blinking (%)	Winking (%)	Smiling (%)
1	100.0	90.9	100.0
2	83.3	100.0	83.3
3	91.7	72.7	100.0

After the patient smiled twice, an average value of 174 µV with an error of 8.4% was obtained as is shown in Fig. 15. the Smiling, winking and blinking was measured in three persons in order to get different information from the electrodes. Each person did 12 attempts for capturing the effectivity of each facial expression, these results are shown in Table 2.

With the number of successful attempts, the percentage of success was calculated as are shown in Table 2. In Table 3 showing that, the recognition of blinking had an average success of 91.6%, winking had 87.87% and smiling had 94.4%.

After to know the peaks value of the different facial gesture it made the programation to change the degree of each articulation. To can control the rotation of the articulation it used the Emotiv gyroscope. The value

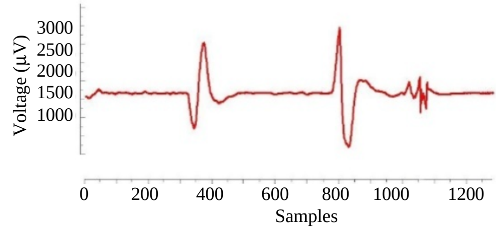

Fig. 16: Gyroscope signal to turn to the right and to at Fig. 16 it can observate the signal obtained to turn the subject head to the right and to the front

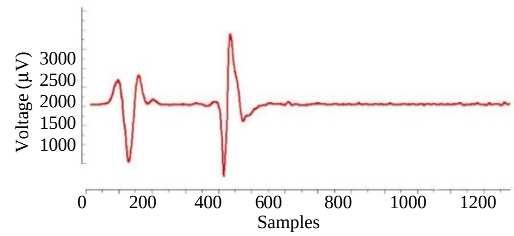

Fig. 17: Gyroscope signal to turn to the right and to the left

Table 4: Number of success attempts for turn with gyroscope

Subjects	Acitors/Attempts	
	Mov.Der	Mov.Izq
1	13/13	12/12
2	12/13	11/13
3	12/12	11/11
4	12/12	12/13

Table 5: Percentage of success for turn with gyroscope

Subjects	Mov. Der (%)	Mov. Izq (%)
1	100	1400
2	92	85
3	100	100
4	100	92

obtained it show at Fig. 16 and 17. In Fig. 17, it can observe the signal obtained to turn the subject head to the right and to the left.

When it turn to the right and to the left, the sensor showed a voltaje less that 2000 µV and when it turned to the left, the voltaje was less that 2000 µV. It can observe when it turn to the left and to the right after that the sensor showed two moves to the left and one to the right it happend because the gyroscope does not have a zero position defined, so, then the gyroscope arrives to a position it uses to stablish in 2000 µV.

It realized t an algoritm to stablish the point when it turn in a specific side, taking as reference the zero position of the subject. According that it sent the instruction to servomotor to turn 10° to the left or right.

The test was made with 4 subjects turning the head to different sides. The results are sowed at Table 4. Finally, it realized the percentage of success the results are showed at Table 5.

CONCLUSION

After made the test of each facial expression was identified if the patient practices more the facial expression, the recognition of this will have major accuracy. Evidence of this is in the twelve tests of blinking, the number 12 had 10% of more accuracy than first test in tests of winking the difference was 8% and in tests of smiling had a difference of 11%.

The recognition of each expression had a success of 91.6, 87.87% and 94.4 for blinking, winking and smiling respectively. These results evidence of great work in recognition of brain signals on the part of processing program.

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