ANIMA: Non-Conventional Interfaces in Robot Control Through Electroencephalography and Electrooculography: Motor Module

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ABSTRACT

ANIMA's primary objective is to compare three non-conventional human-computer interfaces that comply with the industrial robot ST Robotics R-17 instructions. The *Motor Module* presented in this work explains how brain waves are obtained, processed, analyzed and identified according to facial movements produced by the subject. The brain waves are obtained using an electrode cap which complains with the 10-20 international system for electrode positioning. Together with the electrode cap a circuit for acquiring the EEG (Electroencephalographic) signals was designed and constructed. A software tool was designed in order to process the EEG signals using the Fast Fourier Transform technique; with this technique the software is able to identify specific facial movements, and instructions are sent to the robotic arm, executing one of four predefined routines. The system was tested by 5 people, and all of them having successful results. Accuracy achieved by this module was of eighty nine point nine percent.

Keywords: Electronics, Fast Fourier Transform (FFT), Microcontrollers, Electroencephalography (EEG),

1. INTRODUCTION

Research regarding interfaces between machines and the human brain are a major boom nowadays. Some research related to this work has been done at University of Florida and at Pontificia Universidad Católica del Perú. In Florida the researchers designed an EEG Game control based on even-related desynchronization of the premotor cortex when imagining movement (Park and Wankhede, 2002). In Perú, researchers developed an EEG acquisition module which will be used to construct a Brain Computer Interface in the near future (Tupachi et al., 2006).

The brain waves are obtained using an electrode cap applying the technique known as Electroencephalography. The electrodes obtain brain's electrical variations caused by the neuronal interaction. To be able to get these voltages a comparison between electrodes is needed; one is the reference potential electrode and the other is the potential of interest.

The frequencies of the brain waves are in the range of 3 Hz to 30 Hz. Using a Fourier spectrum, which is the graphic representation of the FFT, it is possible to observe the frequency and magnitude of each sinusoid

component represented. Facial movements as eye blinking and jaw clenching can be identified in a Fourier spectrum because they cause a significant change in the magnitudes of the FFT at specific frequencies.

ANIMA has three different modules; the ocular module (Valdeavellano, 2009), the alpha-wave related potential module (Reina et al. 2010) and the motor module. Each module makes its own implementation for moving the robotic arm R17; signals produced by the changes in the electric field of the eyes caused by their movements, brain waves related to alpha activity and brain waves related to facial movements.

The intention of this work is to initiate a new research branch in Guatemala. With the three new interfaces developed by the project ANIMA it is expected to be possible to help people who suffer severe neuromuscular problems like quadriplegia, to be able to control assistant robots.

2. DESIGN OF THE MOTOR MODULE

The Motor module uses facial movements to control the industrial robot ST Robotics R-17. To accomplish this goal the project was divided in three consecutive stages. First, the EEG signals acquisition stage. The acquisition stage consists of amplifying and filtering brain waves coming from the electrodes on the scalp. The second stage processes the brain signals. In this stage a frequency study is made to determine the subject's facial movements; this study is based on FFT analysis. The third stage sends the movement commands to the R-17 robot according to the results from the signal processing stage. Figure. 1 gives a block representation of the stages for the whole *Motor Module*.
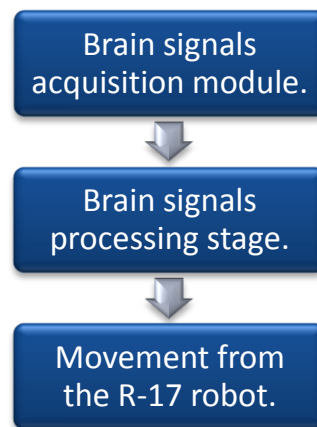

Figure. 1. Block diagram from the Motor module.

3. ACQUISITION OF BRAIN SIGNALS

In this work one of the aims was to design a circuit that could be built with components available in the local market. For the first amplifying stage an AD620 instrumental amplifier was used. This chip is capable of amplifying a signal up to a 1000 times. The circuit implemented by this chip is show in Figure. 2.
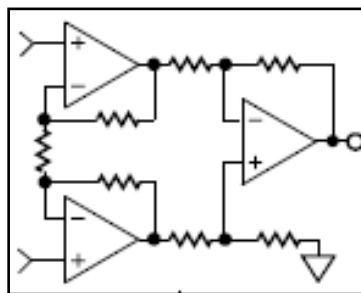
Figure. 2. Instrumental Amplifier.

This amplifier also provides high input impedance which assures a minimum voltage loss in the input signal. With the amplification from this stage the voltages go from the order of the micro-volts to the order of the milli-volts.

To attenuate the frequencies above 35 Hertz an eight-pole low pass Butterworth filter was used with a 35Hz cutoff frequency (Figure. 4). A cascaded high-pass Butterworth filter with a 4 Hertz cutoff frequency was built in order to eliminate the DC-component in the signal (Figure. 4). The output of this circuit is an almost noise-free signal centered in 0 volts but still in the order of the milli-volts. In order to get a signal in the order of volts a second amplifying stage is necessary, for this stage an inverting amplifier was used with a gain between 200 and 300. Finally, a new low pass filter with the same cutoff frequency as the previous was used in order to remove any remnant noise from the signal. After this stage, the circuit output is an EEG signal with amplitude between -2 and 2 volts.

This circuit was replicated in order to have two independent EEG channels which allows to check the waves from the left and right side of the scalp simultaneously.
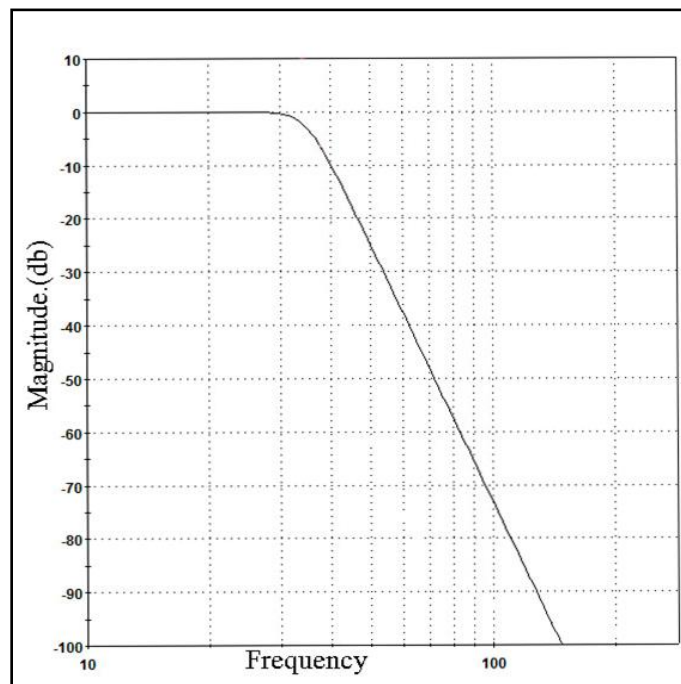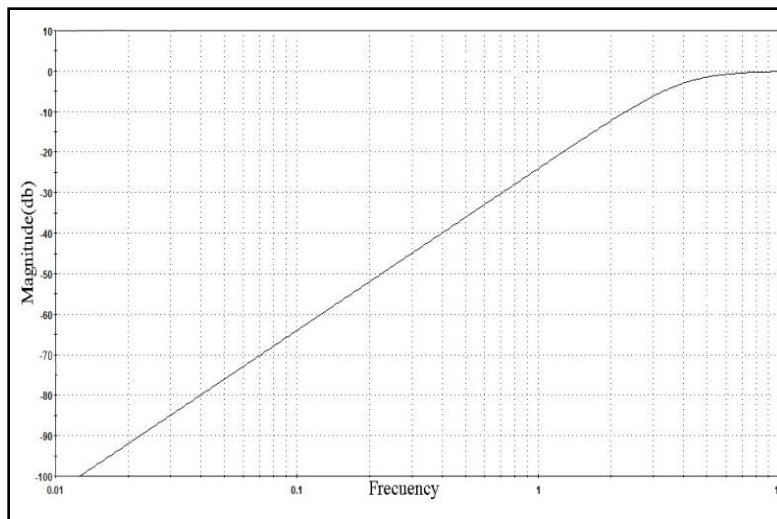

Figure. 3. Bode diagram for the low pass filter.

Figure. 4. Bode diagram for the high pass filter.

4. BRAIN SIGNALS PROCESSING STAGE

For the signal processing, a software was developed using the programming language Python. The software is capable of receiving digitalized data from the circuit and then applies a Fourier analysis.

From the amplifying and filtering stage a voltage between -2 and 2 volts is obtained and to digitize these signals a dsPIC30F3012 was used which works with 0 to 5 volts. A conditioning circuit was used to condition the voltages from the amplifying stage to the filtering stage to be in the 0-5V range. The microcontroller was configured to work at a sampling frequency of 250 Hz or the equivalent to a sample every 4 milli-seconds.

After the microcontroller takes a sample from both channels it sends the data to the computer using the UART module that it has. A 115200 bps transfer rate was used between the microcontroller and the computer.

The computer waits until it receives 256 data (samples) from each channel in order to start any analysis.

The analog to digital converter from the microcontroller allows a conversion of an analog input signal to a 12-bit digital number, so each sample is sent to the computer using 2 bytes, which means that for the 256 samples the computer expects 512 bytes per channel. Altogether the computer receives 1026 bytes, 512 for each channel and 2 bytes for alignment. When the computer finishes receiving the data it proceeds to get the Fast Fourier Transform (FFT) for the data of each channel. The result of the FFT is then plotted showing the contributions of each frequency in the range from 0 to 30 Hz. The software checks if the sum of the contributions of the frequencies between 3 and 6 Hertz is above a predefined threshold. If this condition is true the software knows that the user has blinked (Figure 10). The other range of interest for this study is between 25 and 29 Hertz. If the sum of the contributions of the frequencies in this range is above a predefined threshold the software knows that the user has clenched his jaw. To know if the user clenched his jaw on the left side (Figure 11) or the right side (Figure 12) the software checks on which of the 2 channels the contribution between 25 and 29 Hertz was above the threshold or if it was on both channels at the same time. (Figure 13).

Figure 5 gives a block representation of the circuit built and the modules from the microcontroller that are being used to send the data from the brain waves to the computer.
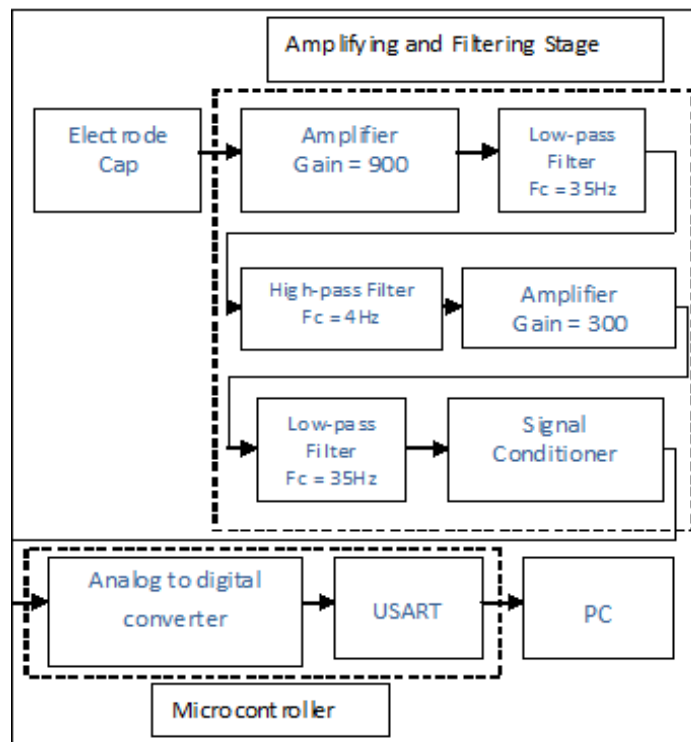
Figure 5. Block diagram of the complete circuit.

5. MOVEMENT OF THE R-17 ROBOT

Robot movements are achieved by RS232 serial communication between the signal processing software and the robot console. A 19.2Kbps rate was used according to the specifications provided by the robot manufacturer. In order to move this robot specific commands should be sent to it. When the software finishes analyzing the brain signal, it sends specific movement commands to the robot according to the results of the signal processing. A correspondence was made between facial movements and the movement that the robot should do. When the user blinks the software sends the command to the robot to move forward. When the user clenches his jaw on the left side the robot will move to the left, when the user clenches his jaw on the right side the robot will move to the right and if the user clenches both sides of his jaw at the same time the robot will move backwards.

This robot is not capable of knowing if a given command will take it to a position that it cannot reach. For this reason the software keeps track of the position of the robot at all time, so if the user asks the robot to go to a position which it cannot reach, the software won´t send the command to the robot and it will tell the user that the movement is not valid. This eliminates the possibility of harming the robot.

6. RESULTS

The acquisition module was tested with an Electrode Cap which places the electrodes according to the International 10-20 System of Electrode Placement. For the tests the C_3 and C_4 electrodes were used, these electrodes were referenced to an electrode that can be used as Ground according to the cap manufacturer. This electrode is positioned beneath the F_z electrode.

Figure 6 shows the output of the EEG signals acquisition module.
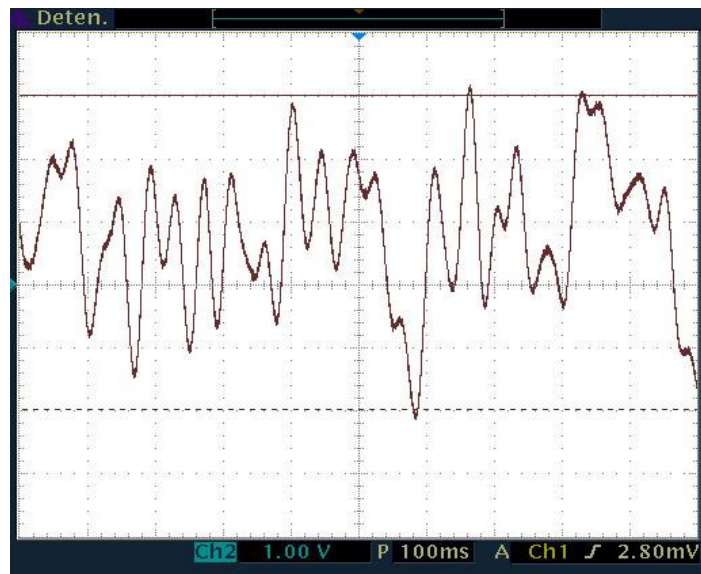
Figure. 6. EEG signal obtained using either C3 or C4.

In Figure. 6 it can be observed the EEG signals obtained using either the electrode C3 or C4. Electrode C3 is on the left side of the head and electrode C4 on the right side.
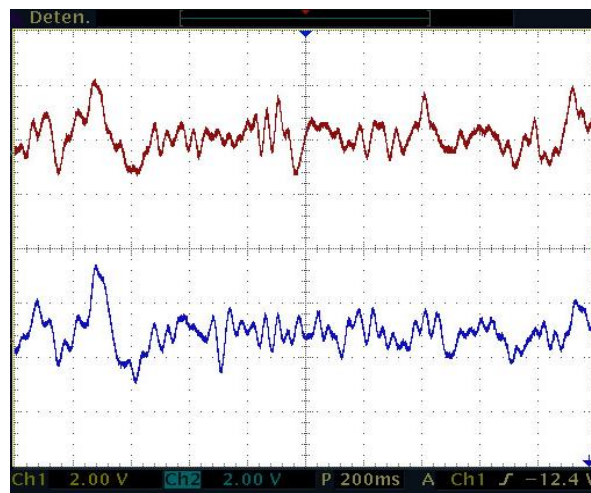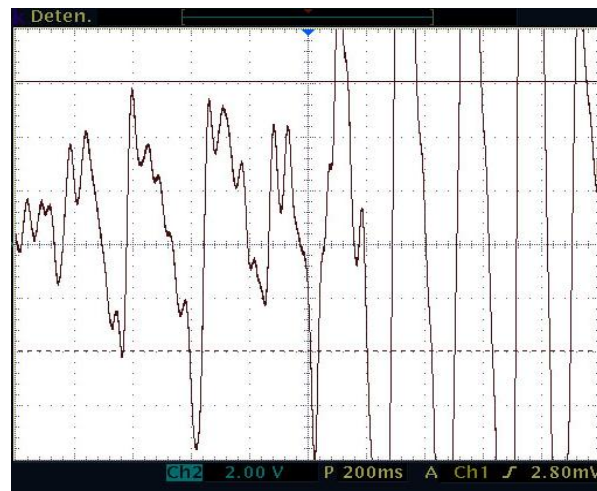

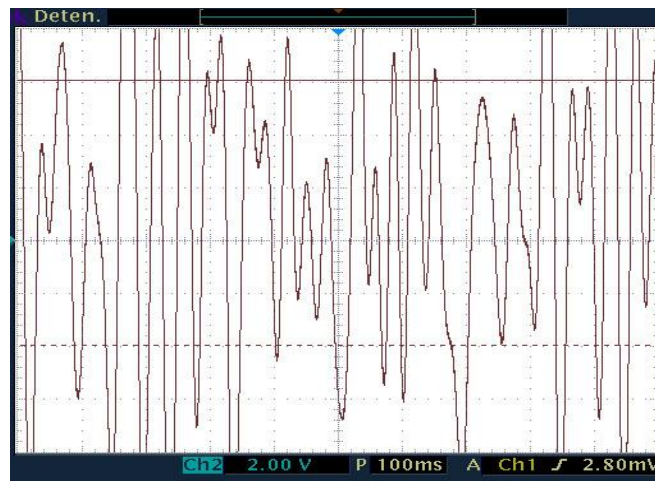**Figure. 7. Signals from both channels working independently.**

In Figure. 7 it can be observed how both channels work independently although the signals are very similar.

In Figure 8 and in Figure 9 it can be observed the distortion in the electric signal due to eye blinking and to jaw clenching.
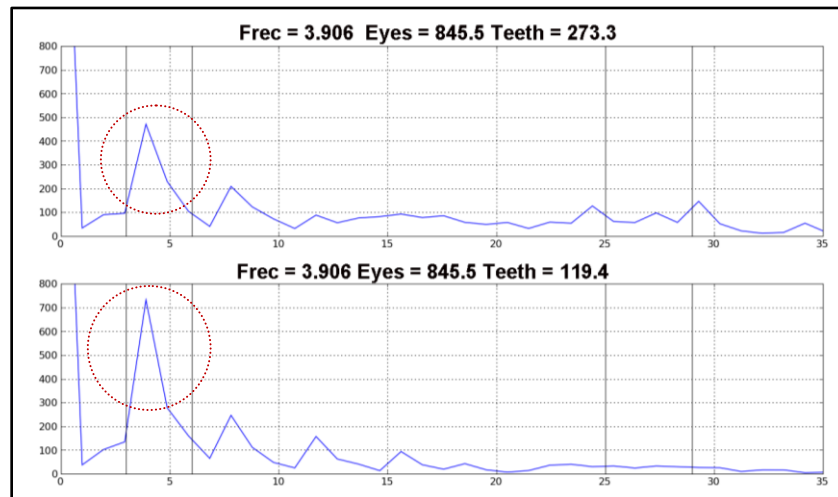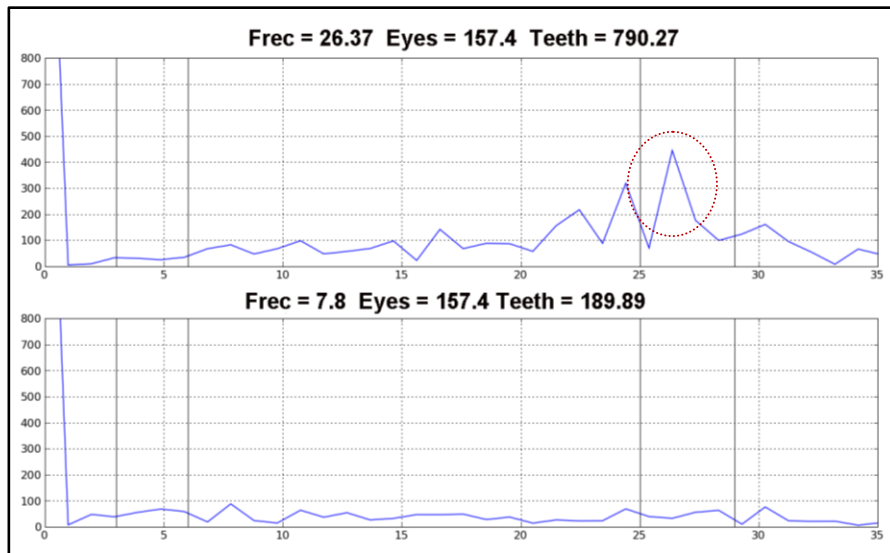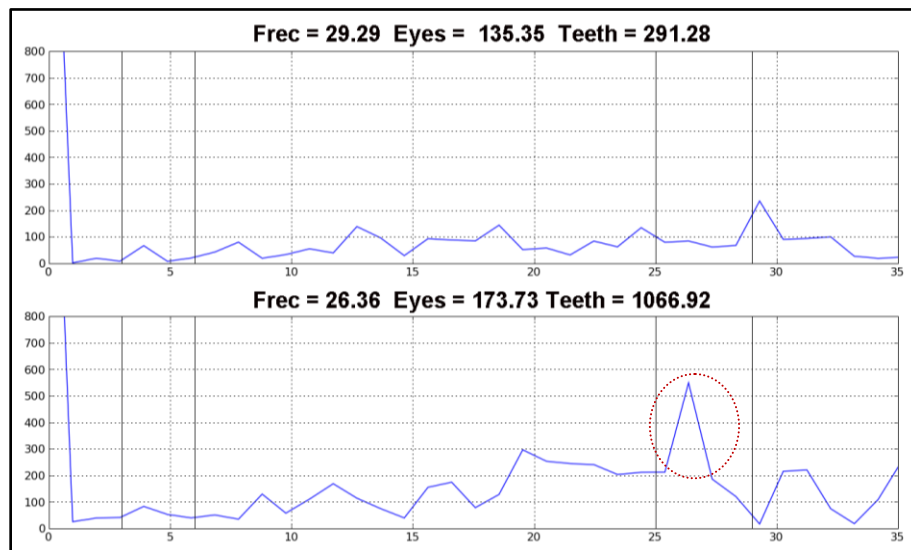
Figure 8. Signals due to eye blinking.

Figure 9. Signals due to jaw clenching.
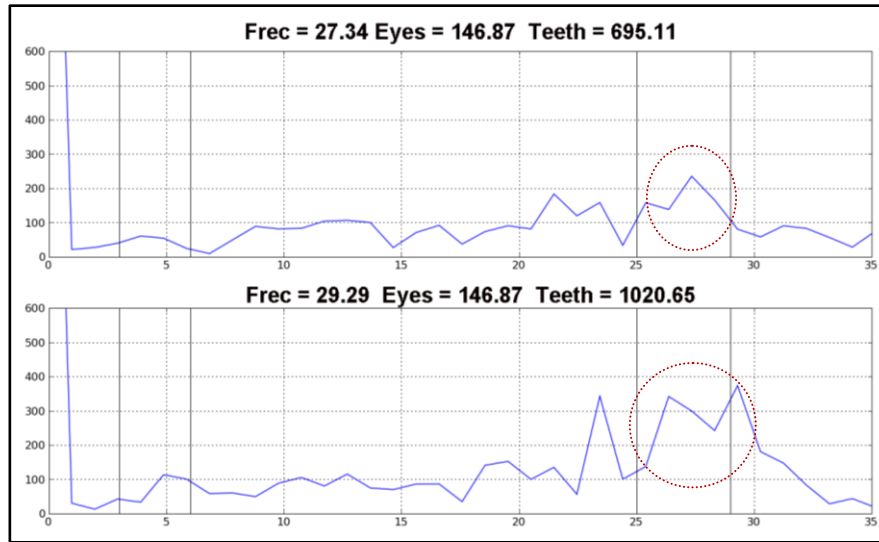

Figure 10. Contributions due to eye blinking.

Figure 11. Contributions due to jaw clenching on the left side of the jaw.

Figure 12. Contributions due to jaw clenching on the right side of the jaw.

Figure 13. Contribution due to jaw clenching on both sides of the jaw.

Figure 10, 11 and 12 show the software capability to recognize the 4 task used by the motor module (eye blinking, left and right jaw clenching and jaw clenching on both sides). The software shows the contribution in the corresponding frequency range, when the different tasks are performed by the user.

A specific routine with 16 commands was performed by the same user 10 times. The results are shown in table 1.

Table 1. Results from Motor module.

Results from Motor Module	
Total attempts	199
Erroneous attempts	20
Successful attempts	179
Successful attempts (%)	89.9
Accuracy (%)	**89.9**
Average time (s)	**6.1**

The routine consisted on performing the 4 different commands 4 times each in a specific order as fast as possible. All together they added 16 commands.

An attempt was taken into account when the subject made one of the four facial movements described above. If the robot did the movement the subject was expecting, it was taken as a successful attempt, if the robot did a movement that wasn´t the desired by the subject, it was taken as an erroneous attempt.

The average time was calculated as the total time to complete the 16 commands (taking into account successful and erroneous attempts) divided by 16. The *Motor Module* turned out to be the fastest module out of the three techniques tested (Motor, Ocular and Alpha-Wave Related Potential) as it needed only 6.1 seconds in average to achieve a command.

7. CONCLUSIONS

A module capable of acquiring EEG signals was successfully built. These signals are then processed and used as specific commands for a robot. The accuracy obtained as well as the average time of 6.1s make this system pretty acceptable to be used in future research for people with neuromuscular problems or physical handicap, providing the user the possibility to operate assistance robots controlled using only his facial movements.

8. FUTURE WORK

Further research and development can be done in order to test with handicapped subjects and develop final useful applications for these people.

Auto-calibration could be possible with further analysis so that the system would initially analyze user's brain activity and auto-set digital potentiometers to adjust gains, offsets, etc.

Mathematical tools like PCA, ICA, wavelets and multivariable statistical signal processing should be used to improve the processing algorithm.

REFERENCES

Park, and M. Wankhede, "A simple approach to   EEG-based control." 2002 Electrical and Computer Engineering, Biomedical Engineering, Univesity of Florida. http://www.picobay.com/projects/EEG-Based_Game_Control.pdf.

P. Tupachi, J. Piñeyro, R. Callupe, R. Alvarado, "Design of an Electroencephalogram Module for Brain Computer Interface Oriented to People with Motor Disabilities." *Third International Conference on Electrical and Electronics Engineering*. 2006, pp 1-5.

Reina L., Martínez G., Valdeavellano M. Destarac M., Esquit C., ANIMA: Non Conventional Brain Computer Interfaces in Robot Control Through Electroencephalography and Electrooculography: ARP Module. In: J.A. Carrasco-Ocho

Valdeavellano, M. R.(2009), "Megaproyecto ANIMA: Métodos no convencionales de interfaz en el control de robots a través de la electroencefalografía y la electrooculografía modulo ocular," Guatemala. School of Engineering, Deparment of Electronics Engineering, Universidad del Valle de Guatemala.

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