Studies of vocal tension in engineering and linguistic degrees using EEG signal processing

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Abstract *— This work has been developed for Engineering and Linguistic studies about signal processing algorithms and articulatory tension of speech sounds. A educational unit is presented related to the study of the tension generated around the mouth is presented. To do so, the measures of a portable EEG with 16 channels are used, which captures the muscle signals in 3 points around the mouth. Those signals are analyzed with spectrum-temporary techniques to extract quantifiable parameters like the intensity in the tension, the frequency in the sounds, which appear with each type of sound or the time intervals before and after peak activity times. Engineering students can provide the tool with new algorithms for the calculation of parameters, and the students of linguistics the characteristics of the tension in the sounds. The authors (in alphabetical order) are a multidisciplinary team.*

Index Terms — Signal processing, language sounds tension, EEG.

INTRODUCTION

Currently, university instructors embody new technologies as pedagogical tools, with a view to facilitate the competences the students should acquire in the degrees they are pursuing.

This article presents a software solution for the teaching practices of engineering and linguistic studies, where are allowed to play with the different functionalities the tool has, and to deepen in the theoretical knowledge of the master classes.

To contextualize the development presented in this paper, we are describing briefly how the EEG system Works in EMG way.

At the present time there exist different type of application of the EEG systems, for example EOG or ECG, but in this case it will be used by means of EMG, with the intention of measuring the articulatory tension generated in the pronunciation of phonemes.

The electromyography [1] is a technique for the evaluation and register of the electrical activity generated by the nerves controlling the muscles. EMGs are normally carried out with an electromyography, but in this case we are using an EEG by means of EMG for this purpose.

Currently there are no experiments in that field of linguistics related to the pronunciation of different sounds with the muscular effort or the articulatory tension generated.

Hence, the purpose of this teaching practice is the study of the measurement of the articulatory tension in the pronunciation of different sounds.

METHODOLOGY

For the accomplishment of this research, the following equipment has been used:

- EEG: g.Tec Medical Engineering.
- Amplifier: g.GammaSys.
- Software for recording: g.Recorder.
- Software for the analysis: g.BSanalyzer.
- Electrodes: Ladybird.
- Video camera.
- Filters: band pass 5-500Hz [3]-[4].
- Sampling frequency: 1200Hz [3]-[4].

The EMG measurements can be undertaken intramuscularly or superficially [1]; in this case, it is carried out superficially. The potential energy generated by the muscle cells when they are activated will be registered.

In this study, we shall carry out the measurement of the articulatory tension generated by the pronunciation of different phonemes belonging to the plosive series (/p-t-k/, /b-d-g/), aimed at establishing objectively some parameters of the recorded EMG signals, like time and amplitude. Furthermore, statistical measures like means, deviations and asymmetries are also evaluated.

Tests are undertaken in a soundproof room. Three electrodes are placed to the subject, configured in EMG way through the recording software g.Recorder.

The first electrode is placed in the middle of the upper lip, the second one in the middle of the lower lip and the third one in the chin.

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The specification of the location of the electrodes was previously arranged with experts in the field of phonetics.

In addition to the previous placement of electrodes, some experiments with other positions and different number of electrodes are being conducted. [2]- [3].

Repeating a given phoneme 20 times, in the case of the tests conducted will carry out the test; the study is focused on the articulation of /p/ and /b/ phonemes.

The synchronization of the measurements will be carried out through a video recording, since, this way the exact instants in which the articulation of the phoneme has been made are obtained.

Pre-Processed Techniques

Once these recordings are completed, the filtering process of the signals gathered in the recording will be undertaken.

The data obtained will be converted to the ASCII format, where interest-free sections will be deleted and the possible artefacts generated by movements or subject's incorrect articulations will be observed.

The processing is exactly the same for each one of the recording channels, undertaking individually for each one of them.

The processing is as follows:

First of all, the arithmetic mean [3] of the electrical activity registered for a given phoneme in the recording will be calculated.

Then, the Fourier transform [3]-[4] will be generated to turn the measurements into the frequency domain, since, this way, we shall obtain the frequency peaks.

Subsequently, the standard deviations of the recordings in addition to their asymmetries will be calculated. [3].

The calculation of the standard deviation is carried out to obtain a measurement of the degree of dispersion of the samples with respect to the average value.

Finally, the asymmetry is calculated to determine the number of deviations with positive or negative sign with respect to the symmetry axis, considering this to be a straight-line parallel to the ordinate axis.

Later the mean delay between the beginning of the muscular effort and the beginning of the phonation will be calculated.

Experience of the Tests

Once the tests are completed, a series of conclusions were obtained from the measurements taken. These conclusions were not possible to obtain due to the absence of appropriate technology.

In the first place, it has proven the existence of broader amplitude in the [b] element in the electrodes of the lower lip and chin, being the opposite in the upper lip, where there is broader amplitude in the [p] element.

Furthermore, we can state that it exists smaller amplitude in the lower lip and the chin.

Finally, we can affirm that the articulation of [p] have a longer duration in the 3 channels besides, implying a greater articulatory tension.

The results have been obtained thanks to a simple and friendly user interface.

SYSTEM DESIGN

The software tool described herein has its strength in the mathematical methods applied to the signals gathered in the recordings.

There is an obligation of undertaking a series of steps in order to eliminate the detected artefacts, interest-free regions, and of preparing the signal for its correct processing involved in working with those signals. [5].

On the whole, the process followed for the undertaking of experiments with the tool is the one which can be seen in the 1 and 2 Figures 2.

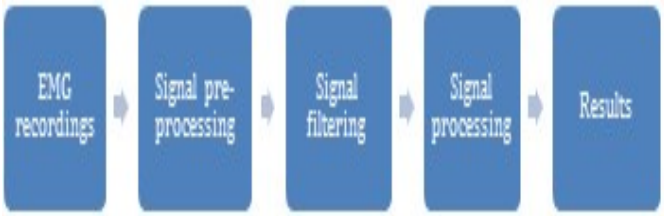

FIGURE. 1
ACCOMPLISHMENT OF EXPERIMENTS PROCESS

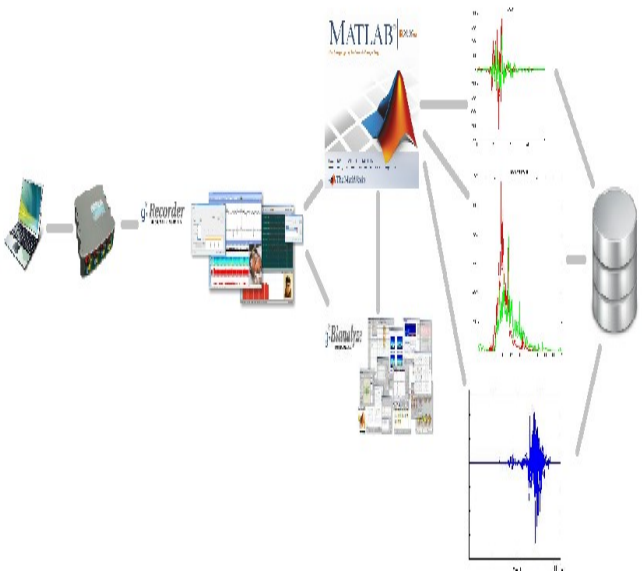

FIGURE. 2
PC + EEG + G.RECORDER + MATLAB +G.BSANALYZE = RESULTS

EMG Signal Recording

For the acquisition of the signals, a PC with a Windows operating system is required. The g.Recorder software will

allow us to select correctly the recording parameters. The sampling frequency [3]-[6], the number of channels to be used, the number of frequencies to sample and the synchronization will be adjusted. The recording process can be seen in Figure 3.

FIGURE. 3
EMG SIGNAL RECORDING PROCESS

Pre-processing of Signals

By means of the g.BSanalyze software, a visualization of the recording will be carried out, giving the support for the elimination of artefacts and application of different filters [7] to prepare the signal for subsequent steps.

Signal Filtering

Using MatLab, a band pass filter will be applied for the gathering of the range of frequencies 20-500Hz [1]-[3]. This adjustment is impossible to be done through the g.Recorder software. In the event of registering a large amount of noise coming from the electricity supply, Notch a 50Hz filter will be applied to eliminate the frequency component of such noise.

Processing

By means of the implementation of an automated algorithm ad-hoc in MatLab, it is allowed to acknowledge automatically each one of the regions of interest of the recordings, that is to say, each one of the articulations of the phonemes, based on amplitude and frequency ranges. Through the developed mathematical algorithms, the calculation of the mean voltages, the frequency graphics, standard deviations and asymmetries will be carried out. In Figure 4 the steps followed by the signal processing can be observed.

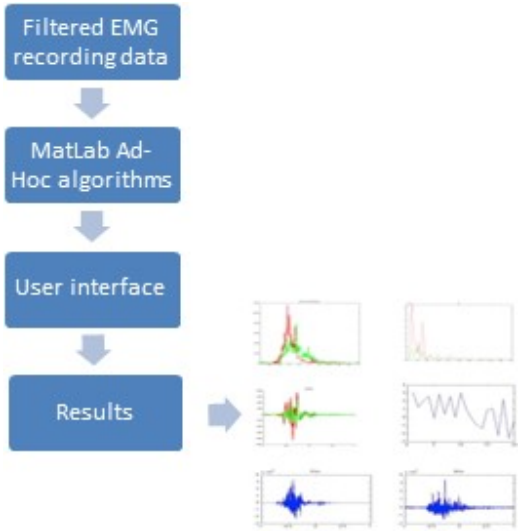

FIGURE. 4
VISUALIZATION AND SIGNAL PROCESSING.

Visualization of Results

Automatically after the processing, the results obtained from the recordings can then be shown by the user interface. This visualization of the results can be seen in Figures 5-8.

RESULTS

For the students to carry out linguistic studies in an objective way, the creation of a multidisciplinary group will be needed, in which experts in the field of linguistics could determine the features to be objectified, and, likewise, engineers could propose the appropriate techniques for the achievement of such studies.

After the accomplishment of the first experiments with the developed tool, the great potential that provides both for future researches and for its implementation in given subjects delivered in studies related to philology and phonetics is foreseen. Exact measurements could be reached, which will allow justifying objectively the theoretical aspects, which so far was impossible to demonstrate due to the lack of appropriate technology.

An example of that is the demonstration of muscular effort in the articulation of different phonemes, in our case the /p/ and /b/ phonemes, from which a greater effort in the first one of them was sensed, but the demonstration could not be achieved.

Using the developed tool, the relevant calculations to demonstrate the previous hypothesis were made. First of all, we base these results in the calculation of the arithmetic mean of the upper lip electrode voltage registered in the articulation

of the phonemes, which can be observed in Figure 5.

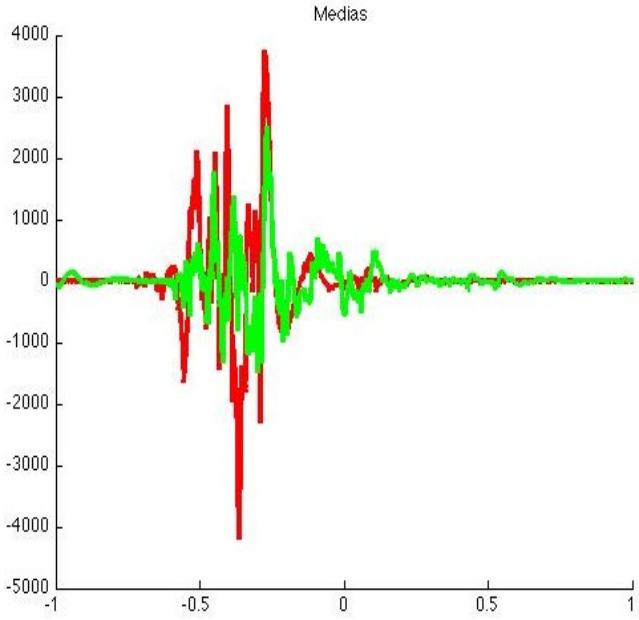

FIGURE. 5
AVERAGE AMPLITUDES OF THE ARTICULATION OF [p] (RED) AND [b] (GREEN).

In addition to this, the Fourier transform is generated with the aim of observing the frequency peaks. The results can be observed in Figure 6.

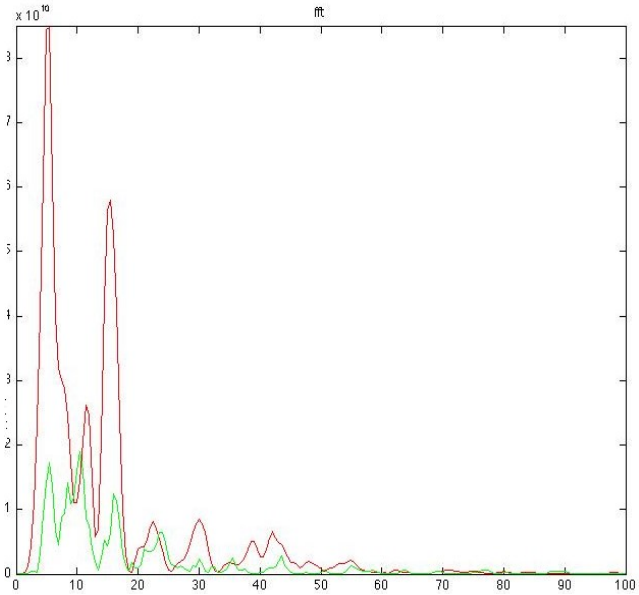

FIGURE. 6
FREQUENCY OF ARTICULATION OF [p] (RED) AND [b] (GREEN).

Finally, the calculations of the standard deviation and the asymmetry (to obtain wave patterns) are made, the results of which are shown in figures 7 and 8.

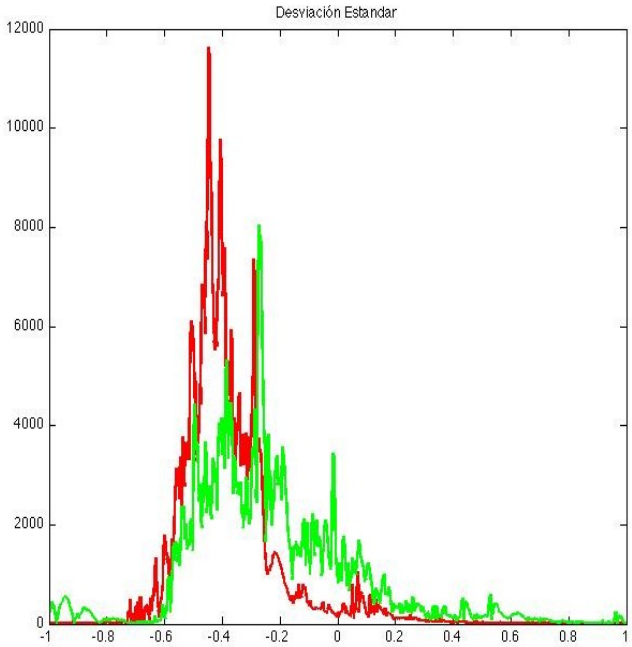

FIGURE. 7
GRAPHIC OF THE CALCULATION OF THE STANDARD DEVIATION OF THE ARTICULATION OF [p] (RED) AND [b] (GREEN).

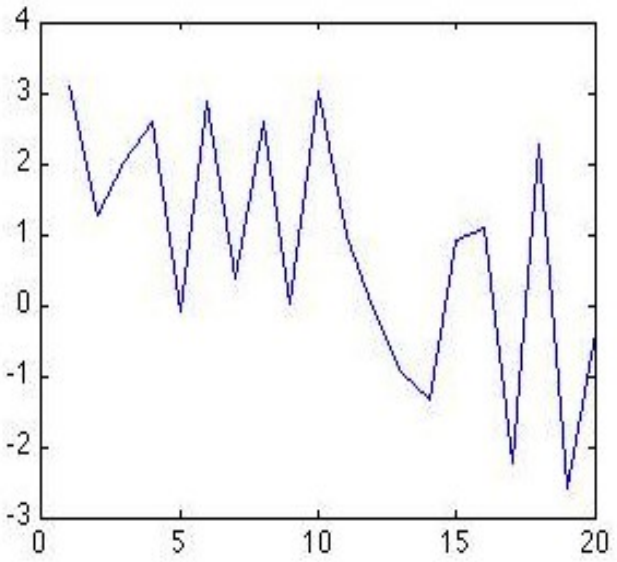

FIGURE. 8
CALCULATION OF THE ASSYMMETRY IN THE ARTICULATION OF A GIVEN SOUND

CONCLUSIONS

The tool developed with educational purposes is currently at test and experimentation stage by students, teachers and researchers.

The group of teachers from the field of linguistics is very interested in this development; since they perceived the great potential for the learning and the scientific results this development may contribute to.

The tool has been developed in a modular in such a way that it is easily scalable, modifiable and easy to integrate with other tools.

The results of the research open both new research lines and teaching methodologies. Previously, it was not easy to measure the muscular effort in the articulatory tension of speech sounds, aimed at determining the differences among them.

Thanks to a very intuitive interface oriented to learning, it provides the students with the necessary support in their studies, in which they could demonstrate several technical aspect in a simple and friendly way.

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