# Didactic Platform for Biomedical Signal Processing: Module for Electroencephalography Signal Digital Filtering

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## Abstract

Recent studies about Biomedical Engineering issues, which are subjects offered in Electrical Engineering undergraduate courses in Brazil, have shown a great lack of investment. That was the main motivation in developing a Didactic Platform for Biomedical Signal Processing (DPBSP) which consists in a generalized and modular biomedical acquisition board, software to visualize and processing signals and theoretical-practical tutorials which aggregate contents to practical class schedules. This work develops a module to support the teaching/learning process of digital filters applied to biomedical signals in the DPBSP. Therefore, we implemented an interactive tutorial, where students can read about the issues relating to digital filtering and all the content that introduces these techniques. The tutorial has Java Applets and routines in Scilab that facilitates the understanding of the content in an interactive way, where the reader is able to read and automatically run what was recently learned, both in theory and in practice. In short, students may have a vision of how digital filters can distort an Electroencephalogram signal, allowing them to learn it in a stimulating and motivating way. Evaluation of the system was realized in two stages. Firstly, students of a regular Electrical Engineering class carried out practical classes. Second, a mini-course of Biomedical Engineering was created for practical work. The motivational aspects like, facility to use, if the system is organized, stimulating and significant, were evaluated through questionnaires. Results of the evaluation showed a very high motivating system with a high expectation for success.

Keywords— Free Software, Didactic Platform for Biomedical Signal Processing, Digital Filters, Digital Signal Processing.

## 1 Introduction

In Brazil, the creation of Biomedical Engineering (BE) subjects in Electrical Engineering (EE) courses at undergraduate levels, aims the perception, by the scientific leaderships in this area, of a huge market for the graduates in EE, as they seek technological solutions in the health area (ADUR, 2007).

Teaching BE depends on an array of contents taught in other classic subjects (usually applied in areas that are also considered “classic” in EE). Nonetheless, the characteristics of the signal and biomedical systems present particularities to be investigated in BE. Furthermore, given the eminently applied nature of these subjects, the referred knowledge and particularities shall be treated in a practical way, through pedagogical approaches that privilege the experience with “making” in this area (ANDRIGHETTO, 2007). In Brazil, though, there are not many subjects assessing these particularities in EE programs.

A preliminary investigation on the insertion degree of specific BE topics in EE undergraduate courses was carried out by Possa (2008). It indicates that only 7,5% of the EE courses investigated offer at least one subject with BE topics. Based on these results, the Institute for Biomedical Engineering of Santa Catarina Federal University (IEB-UFSC) decided to enhance the engineers practical and technical nature, by creating a laboratory for practical BE classes in the EE course.

The creation of the Teaching Laboratory in BE (TLBE) came about with the development of a didactic platform focused on EE undergraduate subjects called “Biomedical Signal Processing System: the Didactic Module (BSPS-

DM)". The hardware, software and tutorial systems included in this platform contribute with the teaching/learning process through experiments in acquisition, processing, transmission, visualization and comprehension of the bioelectrical signal available in the IEB-UFSC Saúde+EducaçãoTM website (http://www.saudeeducacao.ufsc.br) (RATHKE, 2008). This specific work presents the basic module of the BSPS-DM platform, as well as the bioelectrical signal acquisition modules (EEG, ECG, EMG, EOG), the wireless communication module and the Visualization Software.

This specific work consists in the development of one more functionality to the platform DPBSP: The Didactic System of Signal Filtering for EEG.

The Digital Filtering of Signal has stood out as a complex area that requires a high knowledge of the mathematical tools utilized. Therefore, this work presents the creation of an interactive tutorial, using the Saúde+EducaçãoTM as well as the platform DPBSP in which the user has access to contents related to the digital filtering. These tutorials have JAVA Applets and routines in Scilab that support and facilitate the understanding of the contents in an interactive way, allowing the student to exercise, in practice, the subjects that have just been taught in theory.

## 2 Methodology

The system was developed to be made available on the Saúde+EducaçãoTM website and, from the methodological point of view, we present below the used tools, the details of its development and the implementation.

### 2.1 Tools

The following were chosen as tools for the development: The Saúde+EducaçãoTM website, JAVA Applets and the Scilab Sofgware.

JAVA Applets were chosen according to their capacity to adapt to the HTML format, which is the format of the Saúde+EducaçãoTM website. Applets are interesting tools for creating systems where data is processed, because the JAVA Virtual Platform allows the display of graphics integrated with the browser, i.e., the calculated data can be displayed in graphic forms, all of that without the need of executing an exclusive software.

J.M. Kootsey et. all. (2001) describe the use of JAVA Applets as an excellent technology for implementing teaching simulations, because they can easily be combined with text, figures, animations and video. F. Saharil et. all. (2004) state that JAVA Applets integrated with HTML text act as an excellent combination for creating interactive educational websites.

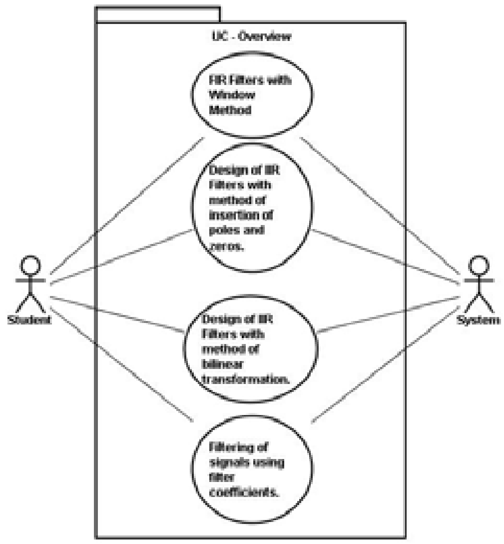
The Scilab itself is a scientific software for numeric computation with a powerful open environment for engineering and scientific applications (http://www.scilab.org). Filtering experiments are, therefore, implemented in this platform and they allow the students to execute them in parallel with the Saúde+EducaçãoTM website tutorials.

### 2.2 Desenvolvimento

The tutorial system was created in the Saúde+EducaçãoTM website through the development and implementation of the following topics: a) Signal and systems in the discrete time; b) Transformed Z; c) Digital Filters; d) FIR Filter (Windows Method); e) IIR Filters (Insertion of Poles and Zeros and the Bilinear Transformation Z); f) Application of filters.

After that, the modeling of the system phase (according to Figure 1) was carried out. This is when the definition of the actors of the system and in which macro-system they are inserted takes place. Explaining, the actor Student uses the tutorial and the actor System makes the calculations and both actors are inserted in the context "Learning Digital Filtering of Signal", which is called General View (which is the use case of Figure 1).

Fig. 1 - General View.

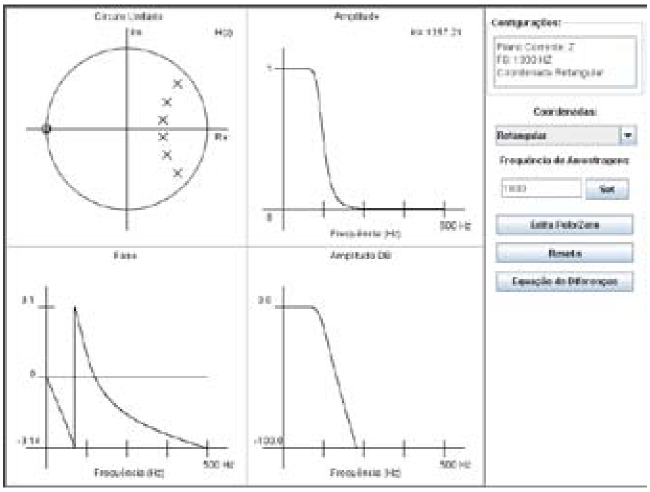



The General View shows which are the subsystems that are part of the tutorial and the actors that have access to each one of these subsystems. The subsystems were divided by contents and for each identified subsystem the need for the implementation of a support Applet was arisen.
At the end of the development the tutorial must be a physical representation of what the General View represents: A tutorial rising four big subjects, an Applet for each subject and a group of functions for Scilab rising each one of these subjects. All of this presented by the System (Saúde+EducaçãoTM website) and making the access of the Student (students that are tutorial users) possible.

### 2.3 Implementation

The functions implemented in Scilab were separated in four groups. Each group contains tools for executing the tasks of each one of the cases presented in Figure 1.
Since these functions are used in the practical part of the tutorials, the group of tools may implement each function independently. Guided by the tutorials, the student may use each one of the tools accordingly, performing more practice through the "Hands to work".
The implemented mathematical tools follow the guidelines suggested by Ifeachor and Jervis (1993).
When the Scilab functions are ready, the Applets were developed, according to the proposed structure in the modeling and through reutilizing the codes of the Scilab mathematical functions. This way, just like the mathematical functions of the Applets and of the Scilab functions, as one is validated, the other one is also being validated in a way.
As an example of the functionalities that were implemented and made available, some examples with their respective discussions are displayed. Figure 2 shows one of the screens that is common in two Applets: in the Applet in which the filters inserting the poles and the zeros directly in the plan Z are projected, and in the one of the bilinear Z transformation method, in which the poles and zeros are inserted in the plan S and the algorithm performs this transformation.

Fig. 2 Applet's Display Screen of bilinear Z transformation and the method of insertion of poles and zeros.



In the Applets that have Figure 2 as the main screen, it is possible to navigate through the menu keys to the right and access screens that make it possible to edit and insert data for the configuration of the IIR filters. It is also possible to extract the coefficients for posterior use, not only in the filter testing Applet, but also in real applications of signal filtering.

Figure 3 shows the screen that makes it possible to visualize FIR filters data generated by the windows method. In the menu to the right of this Applet it is also possible to navigate through FIR filters configuration screens. In this main screen it is possible to visualize the graphic for the sinc function (upper part of the figure) and the answer in frequency of the filter (lower part of the figure). It is also possible to extract the coefficients in order to use them for signal filtering.

Fig. 3 Applet's screen display of FIR Filters.

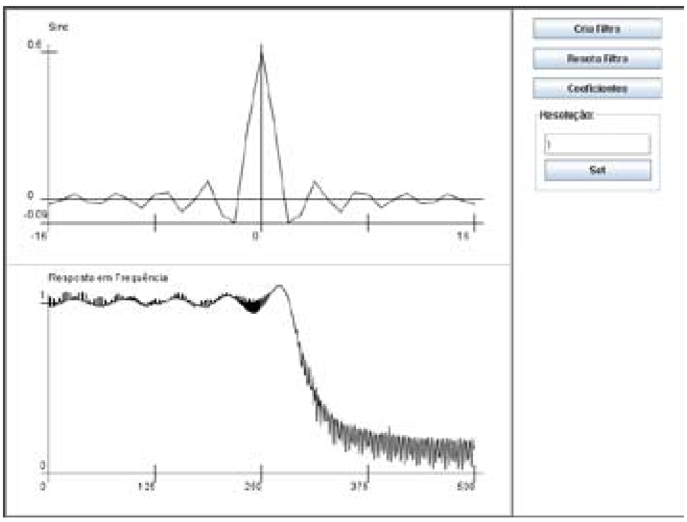
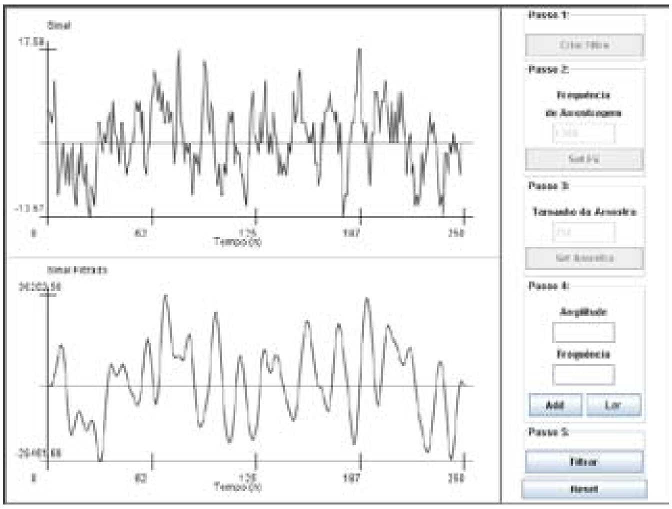


Figure 4 shows the main screen of the signal filtering Applet. It is in this Applet that it is made possible to insert the coefficients generated by the former Applets, to charge a bioelectrical signal (or any sampled signal) and, finally, to execute the filtering and observe the results before (upper part of the figure) and after (lower part of the figure).

Fig. 4 Applet's screen of filtering signals.




## 3 Validation

In a simplified way it is possible to say that the validation is the verification process for the correctness and usability of the system.

From the correctness point of view the Fourier Transformed was used to validate the developed and implemented Scilab and Applets functions. That is, through the Rapid Discrete Fourier Transformed, native function of the Scilab, we can perform a Transformed before filtering a signal and one right after the filtering. It is possible to know, by observing the results, the exact effect of the filter on the signal

Considering each way of the algorithms that need to be tested, it is estimated around six different ways. Although only one of these tests will be presented here, they were executed and concluded successfully.

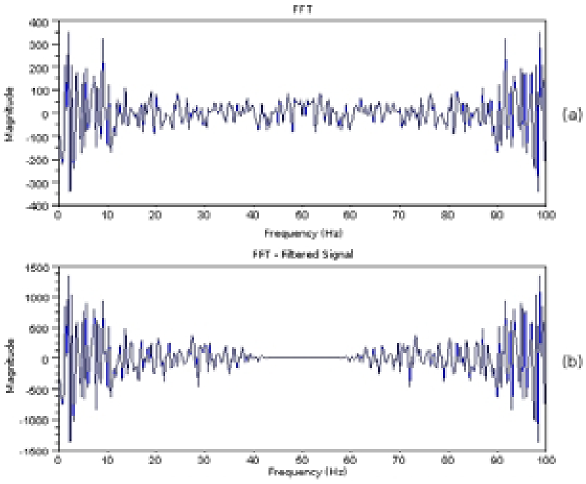
The code that was tested with the Fourier Transformed is one of low pass. It was a Butterwoth filter of fifth order, low pass, with cutting frequency in approximately 35 Hz, transformed by the bilinear Z transformation.

Thus, the employment of a Fourier Transformed before the filtering and one after it, in one signal, should result in a frequency spectrum in which the high frequencies (approximately above 35 Hz) disappear and only the non-filtered frequencies (approximately under 35 Hz) are left.

An EEG (Electroencephalogram) signal was randomly picked in order for the filter to be tested. This signal has frequencies between 0-50 Hz, chosen band, because the signal is sampled in 100 Hz.

Figure 5 (a), shows the rapid Fourier Transformed (FFT) of the original signal, which is the native version of the Scilab for Fourier Transformed. Figure 5 (b), on its turn, shows the FFT of the filtered signal. By observing the FFT of the filtered signal (b), one concludes that the filter acted correctly, beginning the attenuation in approximately 35 Hz, going gradually down until it reached a point where the frequencies were attenuated in very high values, as expected.

Fig. 5 (a) Fourier Transform of the original signal. (b) Fourier Transform of the filtered signal.




## 4 Evaluation

Being this a Web system, the WebMac Senior (4.0), which consists in a form applied to the users, was chosen for the evaluation. The evaluation using WebMac Senior includes the application of a form proposed to a group of users of the product, focused in four attributes. The degree of compliance between the risen matter and the evaluators individual experience in the use of the product, through 32 questions, is measured in it (SMALL and ARNONE, 1999).
The test was performed with two distinct groups of students: one of them, a group of students in the II Mini-course of Practical Biomedical Engineering, held in the Santa Catarina Federal University; the other group was a group of students in the Electronics technological course, in the CEFET-SC.
Among the two of them, the results of the group in the Mini-course is the one of higher relevance, because the participants are students in Electric Engineering or similar areas, and these students are the target public of this work. The vision of the Electronics students in the CEFET-SC were considered for a critical analysis of the tutorials quality. In Figure 7, it is possible to visualize the result of the evaluation performed with the group in the Mini-course of Practical Biomedical Engineering.
By analyzing Figure 6, one can conclude that the Website presents a high value and a high chance of succeeding.

Fig. 6 WebMac 4.0 result for the evaluation of the system.

## 5 Conclusion

The learning system described in the present work includes software tools that may represent an effective support to the study and understanding of biomedical signal processing themes. From the assessments carried out during regular disciplines and mini-courses, the students acknowledged the tutorials and experimental procedures on electromedical apparatuses and the possibility to work on simulated or real biomedical signals, as major advantages of the system in support learning on interdisciplinary themes, suggesting that this approach deserves further developments.

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