Didactic Platform for Biomedical Signal Processing: Modules for Acquisition of bioelectrical signals, A/D - D/A Conversion and ZigBee Wireless Network

SCOLARO, G. R.[1], AZEVEDO, F. M.[2], RATHKE, J. E.1, POSSA, P. R. C.[3], ANDRIGHETTO, E.[4], ADUR R.[5], MARINO NETO, J.[6]

[1~6]Federal University of Santa Catarina, Electrical Engineering Department,
Institute of Biomedical Engineering
Florianópolis – Santa Catarina – Brazil

azevedo1@ieb.ufsc.br[2]

Abstract

The present paper describes the development of a didactic platform designed to support theoretical and practical learning on Biomedical Engineering themes by Electrical Engineering undergraduate students. This platform, termed "Biomedical Signal Processing System: the Didactic Module (BSPS–DM)", provides integrated hardware and software tools for acquisition, processing, transmission, visualization e comprehension of bioelectric signals. It includes a micro-processed Base Module, that allows the coupling of Bioelectric Signals Acquisition Modules (EEG, ECG, EMG, EOG), Wireless Communication Module and Visualization Software for the acquired signals. Tutorials and experimental procedures on electroencephalography and electrocardiography, associated to relevant aspects of the related electro-medical tools, are presented in connection with the above mentioned hardware, through a portal (Saúde+EducaçãoTM IEB/UFSC - http://www.saudeeducacao.ufsc.br/layout.php). These tutorials include applets and virtual 3D environment resources that were tested during regular disciplines and mini-courses on Biomedical Engineering techniques. Assessment of this system by the students (using Webmac 4.0) revealed high indexes of motivation, usability, significance and organization.

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, 2008).

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, 2008). 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.

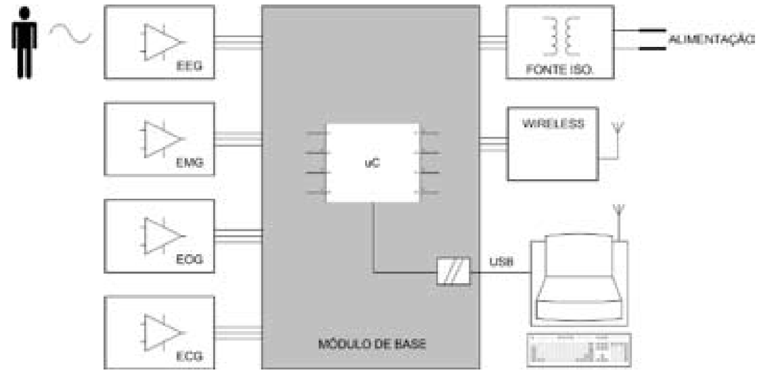
Based on these results, the Institute for Biomedical Engineering of Santa Catarina Federal University (IEB-UFSC) decided to enhance the engineers practical and technical nature, by creating a laboratory for practical BE classes in the EE course.

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/layout.php) (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.

2. BIOMEDICAL ENGINEERING DIDACTIC PLATFORM

In order to facilitate the use and manipulation of each component, the BSPS-DM was projected and implemented as an open and exposed system, identifying all the schematic parts of its electronic circuits.
The proposed system (Figure 01) consists in a micro-processed Base Module, that works as a platform for the coupling of signal acquisition modules (EEG, ECG, EMG, EOG), wireless communication module and Visualization Software that present the acquired signal in a microcomputer (ADUR, 2008).

Figure 01 – Representative scheme of the Biomedical Signal Processing System – Didactic Module (BSPS-DM).



The particularity involved in the creation of this system was the elaboration of a didactic solution concerning the acquisition and processing of biomedical signal. Based on this purpose the equipment was developed with an open architecture that provides the student with the possibility of interacting with the system. For that reason, some resources such as exploring gauge, student circuit and test signal have been created.

2.1 BASE MODULE

The Base Module (Figure 02) forms the central part of the BSPS-DM and its primary function is to promote the interface between the didactic modules and the signal visualization software. Its main component is the ADuC7026 microcontroller by Analog Devices. The Base Module not only digitalizes the didactic module signal, sending it to the computer, but it also makes feeding, + 5 V, -5 V, +3,3 V e GND, available to all of the circuits.

Figure 02 – Base Module developed for the BSPS-DM.

Another resource available in the BM is the generation of analogical signal, that is used for testing the didactic modules. This signal is recorded in the microcontroller firmware from a vector of points. It is converted in analogical signal by the D/A converters, of the microcontroller, and made available as simulated signal (synthetic) that can be used in tests and in measurements in practical classes as an alternative to the placement of electrodes (RATHKE, 2008). Besides, this module allows conversion experiments A/D and D/A.

2.2 EEG DIDACTIC MODULE

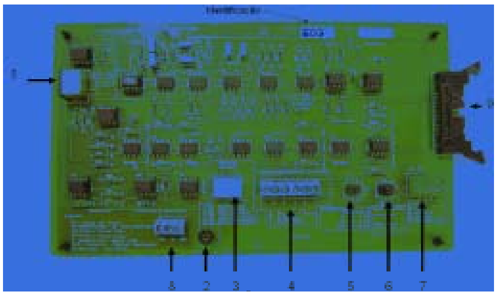
The EEG Didactic Module (Figure 03) works as an auxiliary tool for the study of EEG signal and the effects of filtering in the conditioning chain. In order to do so, the option was to develop a hardware that was capable of acquiring and conditioning signal of up to six channels of EEG.

Figure 03 – EEG Didactic Module.

2.3 ECG, EMG AND EOG DIDACTIC MODULE

The signal (ECG, EMG e EOG) acquired by this module (Figure 04) can be used in practical classes, either in situations of real signal acquisition, or through the use of synthetic signal. The filtering system uses a second order low pass filter, a notch filter of 60 Hz in order to eliminate the noises caused by electric interference, a second order high pass filter to eliminate low frequency signal and a second order low pass filter to eliminate high filter signal avoiding, therefore, aliasing (RATHKE, 2008).

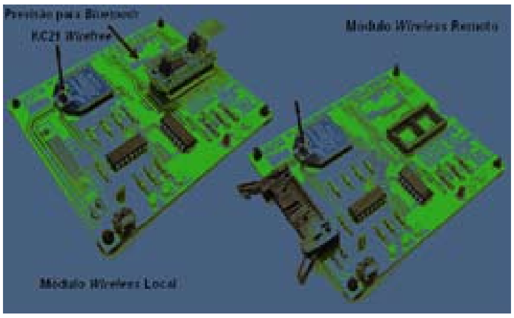
Figure 04 – ECG, EMG and EOG didactic module resources. (1) Electrodes cable connector, (2) Proof gauge connector, (3) Circuits enabling key, (4)
Circuits outputs available to the student, (5) Jumper for the selection of the proof gauge gain, (6) Jumper for test signal / electrodes signal selection, (7)
External circuit signal entry connector, (8) External circuit feeding connector, (9) Connection to base module connector.



2.4 WIRELESS TRANSMISSION MODULE

The wireless communication modules (Figure 05) compose the ZigBee wireless network containing in the BSPS-DM. They allow the computer to remotely work the signal generated in the acquisition modules. Both modules operate according to the topology of the point-to-point network. The local communication module, when connected to the microcomputer, has the function of a master in the network. The remote communication module, along with the BSPS, operates as a slave. These modules also provide a forecast for future connections of the Bluetooth KC21 Wirefree device, in the need of a raise in the BSPS transmission rate – microcomputer (ANDRIGUETTO, 2008).

Figure 05 – Implemented Wireless Modules.



2.5 VISUALIZATION SOFTWARE

The Visualization Software (Figure 06), an integrating part of the BSPS-MD, works as an auxiliary tool for practical classes, promoting visualization resources of the signal that is acquired and conditioned by the other modules and is sent to the microcomputer through USB communication. It also accepts the synthetic signal existing in the BM firmware. It was developed in C++ Builder 6.0 and the following resources are made available to the user: a) Visualization of up to six simultaneous channels; b) Predefined choice of up to six amplitude scales; c) Predefined choice of four time scales; d) Independent movement of the base line; e) hardware activation keys; f) Image capturing in JPEG format; g) Configurations of the communication rate (predefined in 115.2 kbps); h) Selection configuration of the communication door; i) Configurations of the actualization rates on screen; j) Size configuration of the Signal reception buffer; k) Configuration of the amplitude scales; l) Configuration of the activation codes predefined on the BM.

Figure 06 – Detail of the visualization software resources.

3. TUTORIAL

The tutorial's objective is to help the students develop the desirable abilities and knowledge in the BE area. These abilities and knowledge include recognizing, understanding, developing and using mechanisms of acquisition, amplification and filtering of biomedical relevance.

Electroencephalography, electrocardiography, electromiography and electrooculography are topics that were gone into in depth in the tutorials and that allow the raising of many important aspects of the corresponding electromedical equipments. In the tutorials it is possible to investigate the general characteristics of the electrophysiological signal (origin, magnitude and frequency), the acquisition methods (transductors, electrodes and skin-electrode interface), the different forms of filtering, the remote transmission, and the artifacts and electric interferences (deformations in the acquired electric signal). It is still possible to study the technical norms that are in force in construction, maintenance and use of electromedical equipments, aside the norms related to the users safety (RATHKE, 2008).

Guides for practical classes with many experiments were developed. These guides present an initial content with concepts and basic fundaments about the subject to be raised. Moreover, they present detailed information about the use of the hardware components (base and didactic modules) and visualization software. Figure 07 is an example of the topics raised in practical classes.

Figure 07 – Summary of the item "Hands to Work" of the tutorial about electrocardiography.

4. HANDS TO WORK

4.1 Getting to know the Base Module and the Visualization Software
4.1.1 The Base Module
4.1.2 The Visualization Software

4.2 Practical Class 1: The Acquisition and the Amplification of Biopotentials
4.2.1 Introduction
4.2.2 The Instrumentation Amplifier
4.2.3 Getting to know the MIAB
4.2.4 Guide for Practical Class

4.3 Practical Class 2: Conversion Analogical/Digital and Biosignal
4.3.1 Introduction
4.3.2 Choosing a Converter A/D
4.3.3 The Signal Conditioning
4.3.4 Getting to know the MDECG
4.3.5 Practical Class Guide

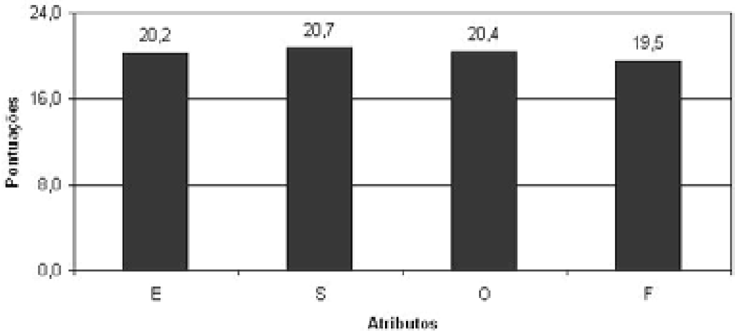
4. SYSTEM EVALUATION

In order to evaluate the system, two EB mini-courses were held in practice. In them, the students performed the setting up of the experiments containing in the practical classes guides. The goal was to evaluate the performance of the system in a real usage situation. The students were advised to previously read the tutorial and the practice guides containing in the Saúde+EducaçãoTM website (RATHKE, 2008).

At the end of every mini-course a questionnaire (Webmac 4.0 Senior (ARNONE & SMALL, 1999)) containing questions about the system was employed as a means to evaluate four aspects: if it is motivating, easy to use, significant and organized. The results obtained by the employment of this evaluation methodology are summarized in Figures 08 and 09.

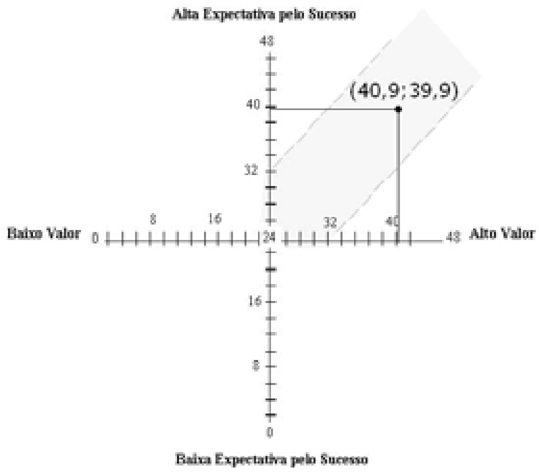
Figure 08 shows the graphic with the grades referring to each attribute of the system. In this graphic the side scale shows the grades of each attribute, being 24 the maximum grade, corresponding to eight questions of 3 points to each attribute. The attributes E (stimulating), S (significant), O (organized), F (easy to use) (RATHKE, 2008).

Figure 08 – Grades of each attribute of the platform.



The graphic containing the grading value of the total motivational qualities in function of the expected value is shown in Figure 09.

Figure 09 – Graphic demonstrating the success expectation in function of the value attributed to the grading of each attribute, in this case the coordinates V and XS are worth 40.9 and 39.9 respectively.



5. CONCLUSION

The learning system described in the present work includes integrated hardware and 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 extracted from themselves, as major advantages of the system in support learning on interdisciplinary themes, suggesting that this approach deserves further developments.

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