

BIOMONITORING LABORATORY ORIENTED TO SOFTWARE APPLICATIONS DEVELOPMENT

SANDA VICTORINNE PAȚURCĂ¹, S.D. GRIGORESCU¹

¹Faculty of Electrical Engineering, University “Politehnica” Bucharest 313, Splaiul Independentei, Bucharest
E-mail: sanda.paturca@upb.ro, sorin.grigorescu@upb.ro

Abstract. *This paper presents a project-oriented laboratory. It is intended to provide an educational and research environment that stimulates innovative solutions in the growing field of Bioengineering. The authors took the advantages of the emerging technology and the increasing popularity of wearable biomonitoring devices, to teach students the key elements regarding the application of Information Technology in health monitoring. The students were involved in a complex project, along which they gain basic knowledge about the software development for biomonitoring, and apply it to effectively develop common structures and software applications. There are presented the stages of the laboratory work, with illustrations of the applications implementation at different levels of the hierarchy, starting from collecting data from the biomonitoring device, and finalizing with the data visualization by the end-user.*

Keywords: biomonitoring laboratory, project team, software application

1. INTRODUCTION

Biomedical Engineering is a dynamic and fast growing field [1] and an emerging educational domain. On one side, the advancing medical technology demands qualified bioengineers for conception, design, installation and training in the use of medical instruments and equipment [3], [14]. On the other side, higher education in bioengineering is required to achieve competitive health care and high quality medical services, along with their cost decrease.

Providing low cost health care solutions is an important challenge for medical services. There are many medical sectors where wearable biomonitoring devices represent promising solutions: patient remote monitoring [2]-[3], public health emergencies [5]-[6], mobile telemedicine [2].

The aid brought by these devices is significantly promising due to their benefits from rapidly advancing electronics and communication technologies, decreasing cost, low power consumption, ease of use, noninvasive and popularity.

Wearable devices can measure vital signals such as blood sugar, blood pressure, electrocardiography (ECG) etc., and transmit data to central server, over network. [3], [7], [8].

There are complete commercial solutions of healthcare systems, having the devices integrated in the

communication and data management infrastructure: CardioNet, LifeWatch, Corventis, AMON, EPI-MEDICS, WEALTHY, MOBIHEALTH. [3], [4], [5], [9].

However, considering the variety of applications, expanding technologies and the need for proper implementation of such medical service systems [9], there is a certain need for teaching bioengineering students key concepts about the biomonitoring chain: signal measurement, signal processing, data transmission [7], [8], data storage in databases [13], and the underlying software development.

Moreover, laboratory hands-on projects are mandatory for developing abilities to understand and apply the concepts, making the students able to develop software applications along the chain, from the monitoring device to the end-users – patient and physician.

This paper presents a laboratory focused on software development in biomonitoring. There are briefly described the technical concepts and the equipment, and a teaching approach by means of active learning.

This approach is intended to stimulate creativity and teamwork, by involving the students in complex projects, where each student has a specific role within the project tasks. The main covered issues are:

- Sensors and signal conditioning, communication, all integrated in the wearable device as laboratory classroom equipment;
- Development of PC application for real-time data visualization, processing (e.g. ECG features extraction) and storing, for a specified application scenario (e.g. subjects are members of a sport team);
- Development of database: database server and management, database structured according to the designated scenario;
- Development of client application for user-friendly query and visualization;
- Working with powerful and popular technical software tools: Matlab-Simulink and LabVIEW.

2. TECHNICAL TOPICS COVERED BY THE BIOMONITORING LABORATORY

The laboratory comprises two stages: a preliminary one, focused on basic training, and a project stage, in which the students are involved in working in a team to develop a complex solution of biomonitoring, from a device to a data center and the end users – patient and physician.

2.1 Preliminary stage – working with bio-signals extracted from dedicated databases

The first stage of laboratory consists in acquiring basic knowledge about bio-signals, followed by the development of software modules that perform specific tasks: retrieving stored signals from a database, processing signals, and displaying data. The main tasks in this stage are summarized in Figure 1 and 2.

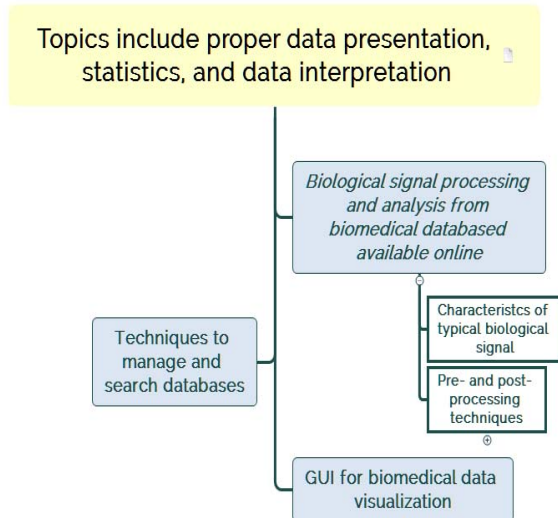


Figure 1. Basic tasks in preliminary stage

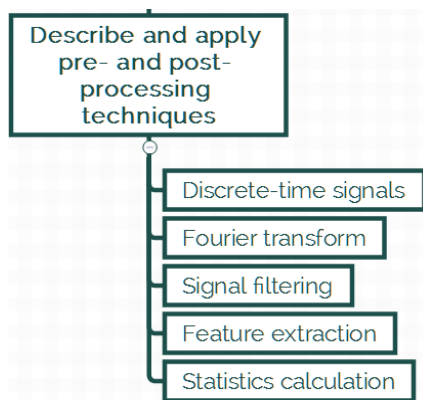


Figure 2. Tasks related to processing techniques

As database it was chosen PhysioNet [15], [16], built and maintained by MIT. It contains a vast and valuable collection of more than 50 different types of medical signals recordings.

There had been chosen ECG recordings to work with. Beside the signal samples, they also contain annotations written by medics on portions of recordings, where known abnormalities of heart functioning had been encountered (e.g arrhythmia).

The first application to be done by the students is to build a LabVIEW application able to extract ECG waveform

from the online database, given the start and end time of the recording, as in Figure 3. It is also required to extract the additional information stored online along with the signal, as in the example below:

- Record: mitdb/100
- Length: 30:05.556 (650000 sample intervals)
- Sampling frequency: 360 Hz
- File: 100.dat

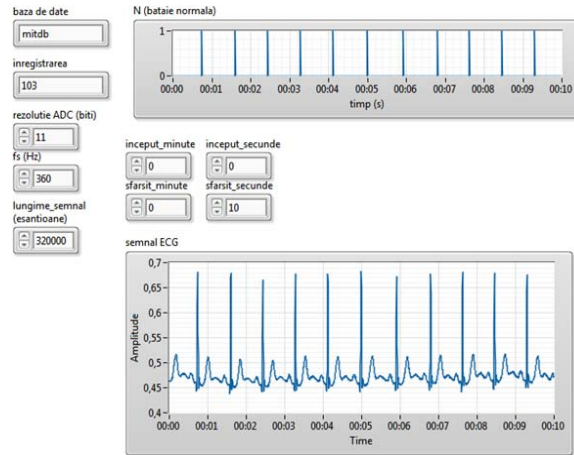


Figure 3. Example of ECG waveform extracted from the online database

Based on the first application, the second one is to search for a certain type of medical annotation, specified by the user, to download the corresponding portion of the ECG waveform from the online database, and to display it graphically in the GUI.

The third application is to perform basic signal processing, as shown in figure 2, using the signals extracted from the database: Fourier transform, signal filtering, statistic calculations, etc. The original and processed signal has to be displayed on the GUI, as in the example presented in Figure 4.

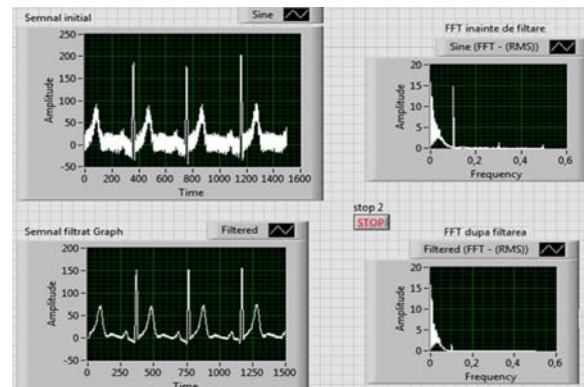


Figure 4. Example of original and processed signal, extracted from the online database

2.2 Project stage

The second stage of the biomonitoring laboratory consists in engaging the students in a complex project, whose

objective is the development of a software solution for biomonitoring, bringing together all the tasks needed to bring data from devices to a local monitoring point, collect data into a structured database, to be available for the user in a meaningful manner.

The tasks involve the development of software structure and applications for: acquisition bio-signals from a biomonitoring device, pre- and post- processing of bio-signals, local monitoring point and datacenter. The basic tasks in this stage are summarised in Figure 5.

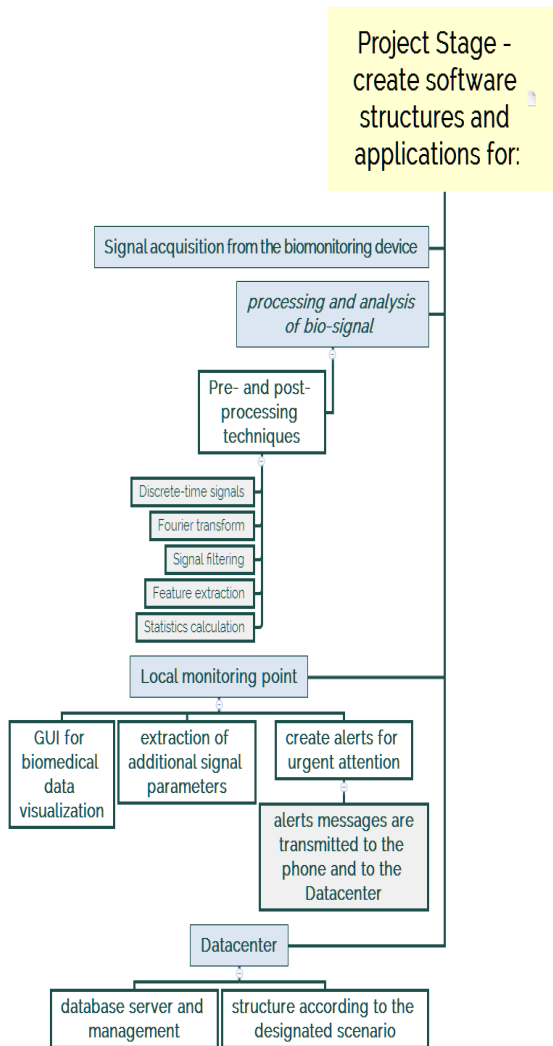


Figure 5. The tasks in the project stage

The project was conceived as a solution for a common utilization scenario: a multi-patient biomonitoring system, in which the vital bio-signals have to be continuously collected and transmitted to a specialized medical center to be processed, interpreted and stored in databases, for further query, visualization, evaluation etc.

The project follows the real utilization scenario, in a simplified manner: data are collected from multiple biomonitoring devices, transmitted wirelessly to a monitoring point (laptop). Further, data from multiple monitoring points are transmitted by internet to a

datacenter, which is a SQL database server [10]. At this level, data is available to the user, by means of a client application, able to make queries according to the user requests for visualization. The block diagram of the multi-patient monitoring system aimed by the biomonitoring project is presented in Figure 6.

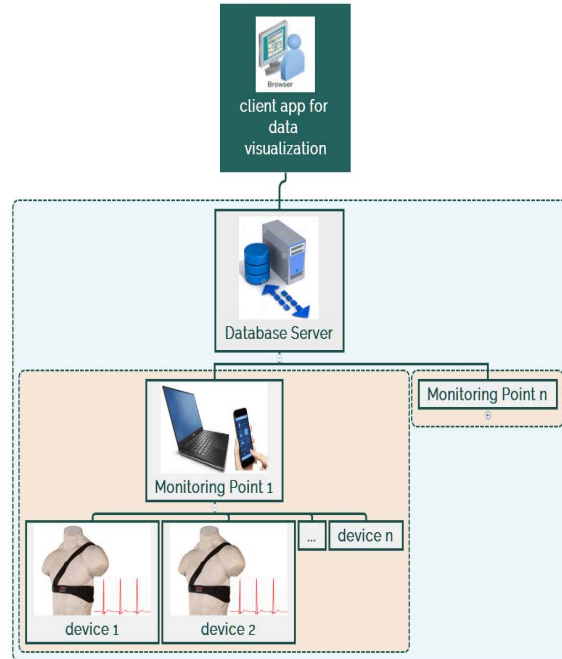


Figure 6. The block diagram of the multi-patient monitoring system, aimed by the project

As biomonitoring device, it was chosen Zephyr Bioharness3 development kit [17], consisting in a wearable chest belt having ECG, respiration, temperature and body posture (accelerometer) sensors, and wireless module (e.g. Bluetooth communication, with serial protocol for developers) (Figure 7).



Figure 7. The biomonitoring device utilized in the laboratory - Zephyr™ BioHarness 3 chest belt [17]

The device block diagram of the device is illustrated in Figure 8.

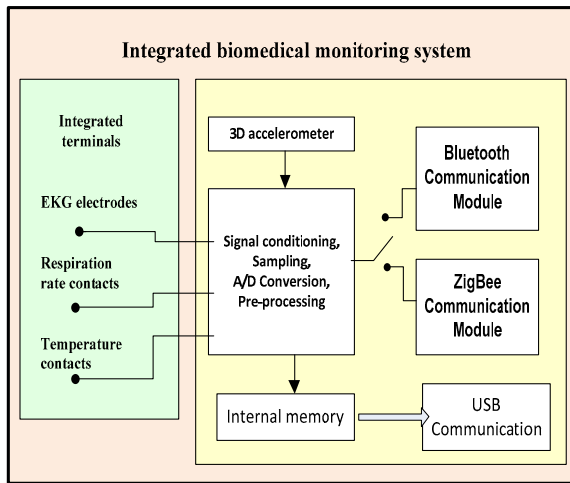


Figure 8. The block diagram of the biomonitoring device

The database is structured according to the following general scenario: each biomonitoring procedure is organized as an event, whose participants are the monitored subjects, wearing the devices.

The following database tables are built accordingly: “Events”, “Subjects”, as illustrated in Figures 9 and 10, and “mp_nn_waveform” – where “mp” stands for “monitoring point”, having the numeral identifier “nn”.

table “events”	
<i>table description</i>	- this table contains the events summary; the events participants are the monitoring points (PC or mobile device) - the connection with the other tables are made by means of the columns marked with bold characters
column name	description
index	table index
event_name	the name of the events whose participants are ‘mp_n’
start_time	date and time of the event start
organizer_name	event organizer
mp_id	unique identifier of the monitoring point (e.g. ‘mp_00’)
mp_location	location of the monitoring point
subject_name	subjects’ name
device_id	device id number (e.g. ‘BG_ECG_001’)
ecg_sampletime_us	sampling time of the ECG signal, expressed in microseconds, for each device

Figure 9. The description and columns of the table “events”

table “subjects”	
<i>table description</i>	- this table contains subjects information - the connection with the other tables are made by means of the columns marked with bold characters
column name	description
index	table index
subject_name	subject’s name
age	subject’s age at the event recording time
gender	subject’s gender
weight	subject’s weight at the event recording time

Figure 10. The description and columns of the table “subjects”

At the monitoring point, an application is built for on-line biomedical data visualization.

Figure 11 shows an example of application GUI, in which ECG samples are represented as waveform, and other numerically data (heart rate, temperature, body posture) are shown.

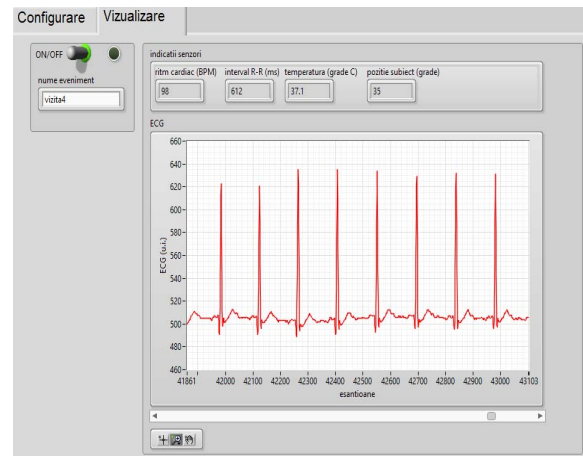


Figure 21. Example of monitoring point application GUI, showing the ECG and other data collected from one biomonitoring device

Finally, the students build patients electronic records, containing:

- Information for the medical staff:
 - Patient data: name, gender, age, general condition, allergies, investigations and diseases records;
 - Alarms occurred during the monitoring, and alarms history;
- Communication between the system members: medical staff and patients (e.g forum);

- Information for patients:
 - Investigations, and their history;
 - Information about the currently available medical staff;
 - Forum.

3. EDUCATIONAL ASPECTS

From educational point of view, the presented laboratory is intended to provide an active learning environment with project-oriented activities, and interpersonal communication [11-12].

The learning instructional approach is organized around the project. The project has moderated to high complexity, mainly due to its inter-disciplinary character.

Project team members are organized in groups, each having assigned a specific task to complete and to present to the other groups. At the completion of a task, the students change the roles, in order to participate in all the project tasks. The teacher plays the role of facilitator and evaluator.

The intended achievements at the project completion are summarized in Figure 12.

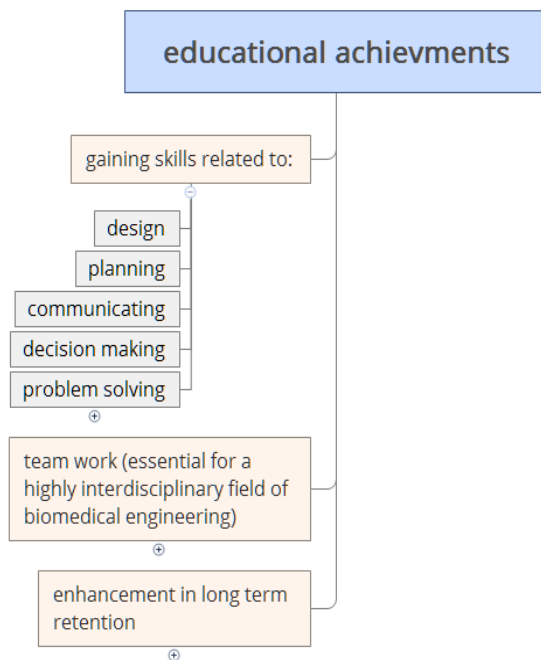


Figure 32. Project educational achievements

At the project completion, the students were asked to fill feedback forms with their opinion about the project and the chosen biomonitoring equipment. The most frequent answers were: "interesting", "motivation and involvement"; "learn how to organize and assign tasks in teams, and watch their progress within time constraint"; "build self-confidence"; "learn to communicate effectively

and share experiences"; "stimulate interest for further explorations in the field of biomonitoring".

The students found the chosen equipment (the chest belt) very attractive, mainly due to its usefulness in everyday life: "keeping tabs on own health", "an interesting fitness aid".

By being involved in the big project with their part of work, students are motivated to do their best at learning and performing for the project success.

4. REFERENCES

- [1] T.R. Harris, J.D. Bransford, and S.P. Brophy, Roles for Learning Sciences and Learning Technologies in Biomedical Engineering Education: A Review of Recent Advances, *Annual Rev. Biomed. Eng.* 4:29–48, 2002.
- [2] World Health Organization, mHealth – New horizons for health through mobile technologies, 2011. www.who.int/goe/publications/goe_mhealth_web.pdf.
- [3] Al. Pantelopoulou and N.G. Bourbakis, A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis, *IEEE Transaction on Systems, Man, and Cybernetics – Part C: Applications and Reviews*, Vol. 40, No. 1, 2010.
- [4] A. Rangarajan, Review: Emerging Trends in Healthcare Adoption of Wireless Body Area Networks. *Biomedical Instrumentation & Technology*, 50(4):264, 2016.
- [5] P. Mohan et al. MediNet: Personalizing the self-care process for patients with diabetes and cardiovascular disease using mobile telephony, In: *Conference Proceedings IEEE Engineering in Medicine and Biology Society*. New Jersey, pp. 755–758, 2008.
- [6] A.M. Paraschiv., C. Cepisca, C. Banica, A. Enache, Remote Monitoring ECG Signals System, *International Symposium on Advanced Topics in Electrical Engineering (ATEE)*, 2011.
- [7] F. Adochiei, I.R. Edu and N. Adochiei, Comparative Filtering Methods for Noisy ECG Signals, *Conference on E-Health and Bioengineering (EHB)*, Romania, pp. 85-88, 2011
- [8] M. Calin, A.M. Dumitrescu, M. Asprou, et. al. Measurement Data Aggregation for Active Distribution Networks, *Conference Proceedings of IEEE Applied Measurements (AMPS)*, Aachen, pp. 144-149, 2013.
- [9] S.D. Deshmukh, S.N. Shilaskar, Wearable sensors and patient monitoring system: A Review, *Conference on Pervasive Computing (ICPC)*, 2015.
- [10] S.V. Pațurcă, *Virtual Instrumentation for Biomonitoring*, Ed. Printech, Romania, 2014.
- [11] R. Lindberg; J. Seo; T.H. Laine, Enhancing Physical Education with Exergames and Wearable Technology, *IEEE Transactions on Learning Technologies*, Vol.PP, Issue: 99, 2016.

- [12] S.V. Pațurcă, C.K. Bănică, S.D. Grigorescu, St. Gheorghe, Software Platform for Patients Biomonitoring Using Wearable Devices, *Journal of Biotechnology*, vol. 231, pp. S104, 2016
- [13] S.A Hameed., S. Mustapha, A. Mardhiyah, V. Miho, Electronic medical record for effective patient monitoring database, *Computer and Communication Engineering (ICCCE)*, 2008.
- [14] J. Fleming, R. M Iyer, M. Shortis, H. Vuthaluru, K. Xing, and & B Moulton, Biomedical engineering curricula: trends in Australia and abroad, *World Transactions on Engineering and Technology Education*, Vol.10, No.1, 2012
- [15] <https://physionet.org/>
- [16] A. Goldberger, L. Amaral, L. Glass, J Hausdorff, P. Ivanov, R Mark, J Mietus, G Moody, CK Peng, H Stanley. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* 101(23):e215-e220
<http://circ.ahajournals.org/cgi/content/full/101/23/e215>; 2000; PMID: 10851218; doi: 10.1161/01.CIR.101.23.e215
- [17] <https://www.zephyranywhere.com/>