INSTALLATION AND OUTFITTING OF A LABORATORY FOR INSTRUMENTATION AND BIOMEDICAL MEASUREMENT

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Abstract: This work describes the process followed to install and outfit a Laboratory for Instrumentation and Biomedical Measurement (LIBMM) in Mexico City. The main objective of the LIBMM is to provide a suitable environment for the students to actively face different problems related to Biomedical Engineering (BME), so they would be able to propose and evaluate solutions through the use of diverse approaches and modern technologies. Once a laboratory was supplied with electrical grounding and Internet, a wide set of modern equipment for transducing, conditioning, acquisition and processing of physiological signals was bougth. It was also bougth equipment for electronic measurement and computers tools. Six workstations were constructed and placed in the laboratory, each workstation encloses equipment for: Bioelectric signals adquisition, electronic measurement and computers tools. In order to provide clinical equipment useful to evaluate students projects (or to train students), some specialized BME equipment was also bougth such as Defibrillators, Skill-trainers systems, biochemical analyzers, etc. After four years of operation, the LIBMM has shown satisfactory results. Nowadays students can solve problems by using different technologies and approaches, but there is still much work to do in order to improve the administration of the LIBMM and increase the quantity of experimental material.

Introduction

The BSc in Biomedical Engineering (BME) curriculum was implemented in 1974 at Universidad Autónoma Metropolitana-Iztapalapa (UAMI). At that time, there were no facilities for teaching on the subject of experimental elements about BME [1], especially for physiological signals measurement.

In 1984, the project of a Laboratory for Biomedical Engineering Teaching (LBMET), whose main purpose was to provide practical experience related to the non-invasive measurement of physiological signals, was started [2]. However, since the BME field had been recently introduced in México, the initial laboratories and equipment were not only limited, but also reused, which considerably restricted the experimental work for students. This in turn, produced to be short of laboratory experiments, which additionally were mainly demonstrative. Further, it was common that a practical session was split into two ones, of one and a half hours each, where students only observed a demonstration of how to acquire a bioelectrical signal (ECG, EMG or EEG), how to characterize a pressure transducer, or how to do a biochemical analysis.

In order to deal with the lack of practical support, during the 90's the facilities were quadruplicated, and the process to purchase equipment for instrumentation and biomedical measurement was started. These actions lead to the implementation of an institutional project in 2000: *The installation and outfitting of a Laboratory for Instrumentation and Biomedical Measurement (LIBMM).*

The main objective of the LIBMM was to provide a suitable environment for the students to actively face different problems related to BME, so they would be able to propose and evaluate solutions through the use of diverse approaches and modern technologies. This paper describes the process followed and some results of four years of formal operation of the LIBMM.

Materials and Methods

The project focused on four elements as follows:

1. Laboratory conditioning: By the time this project started, the LBMET was composed by three laboratories, the biggest of them, a laboratory of 9.6 x 7.7 m, was selected and conditioned as the new LIBMM. Once the LIBMM was adapted and supplied with electrical grounding and Internet, it was also beautified to provide students and teachers with a safe, pleasant, and comfortable room to work in.

2. Laboratory outfitting: Despite having some transducers, basic systems for non-invasive measurement of physiological signals (polygraphs and digital acquisition systems), and electronic equipment, those were not enough to reach the objective of the LIBMM.

Before deciding how to complete the outfitting for the LIBMM, two problems were considered: (a) Only four teams used to work during the practical sessions, and sometimes more than a few students did not participate in the experiment, especially when the group size was bigger than sixteen. (b) Some measurement equipment, accessories, software and hardware, that had not been updated in years, restricted the knowledge of new technologies to theoretical aspects. Therefore, it

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was decided to increase and update the available equipment by buying new non-invasive technologies, each one compatible with the basic systems already existed in the laboratory.

The compatibility requirement was so important, because as it was mentioned in the Introduction, even before the LIBMM project was started, the UAMI had previously bought some Biomedical transducers and equipment for data acquisition. In that time, the UAMI had bought the polygraphs, transducers and amplifiers to the NIHON KOHDEN Corporation™ (NK) because of the high quality and modularity of his products. Additionally, as the importance of knowing new technologies had been pointed out, a few digital acquisitions systems, transducers and amplifiers from BIOPAC Systems, Inc™ (BS) had been also bought. This in mind, three categories of compatible equipment were considered: *Specialized Biomedical equipment, General-purpose equipment, and Clinical equipment.*

a). Specialized Biomedical equipment: It was composed by basic systems for measuring physiological signals (polygraph and A/D conversion), novel non-invasive transducers, amplifiers and stimulators; all of them of different technologies, and specialized in biomedical purposes. Table 1 shows a detailed description of classification, name and purpose of the Specialized Biomedical equipment that was considered to outfit the LIBMM.

b). General-purpose equipment: All-purpose equipment for electronic measurement, and different computer tools (software and hardware) were considered to give the students the possibility to develop their own projects. Table 2 gives more information regarding the classification, name and purpose of the General-purpose equipment considered for outfitting the LIBMM.

Table 1: Description of the Specialized Biomedical equipment considered for the LIBMM. Classification, name and purpose of the basic systems for acquisition, non-invasive transducers, amplifiers and stimulators.

Classification	**Name**	**Purpose**
Basic system	• Polygraph	• Acquisition of physiological data
	• Digital acquisition system	• Digital acquisition and analysis of physiological data
Transducers / amplifiers (amp)		Transduction and conditioning of physiological data by detecting:
	Cardiac function	
	• Surface electrode / Bioelectric amp	• ECG
	• Contact microphone / PCG amp	• CGA, PCG, Carotid/Jugular Pulse wave
	• Accelerometer microphone / PCG amp	• PCG (Cardiac Sounds)
	• Dual electrode / Bioimpedance amp	• Cardiac Output
	• Photoelectric / Plethysmograph amp	• Peripheral Pulse wave
	• Cuff / Pressure amp	• Non invasive pressure
	Respiratory function	
	• Accelerometer microphone / PCG amp	• Breathing sounds
	• Dual electrode / Bioimpedance amp	• Respiratory curve
	• Nasal thermistor / Temperature amp	• Respiratory curve
	• Strain-gage / Respiratory amp	• Respiratory curve
	Muscle function	
	• Surface electrode / Bioelectric amp	• EMG
	Brain function	
	• Surface electrode (scalp) / Bioelectric amp	• EEG
	Stress	
	• Electrodermal response / GSR amp	• GSR
Stimulators		Evoking responses from Nervous pathways and Brain
	Somatosensorial pathways and Brain function	
	• Active electrode	• ERS (Somatosensorial Latencies)
	Visual pathways and Brain function	
	• Flash, Pattern, Goggles	• ERS (Visual Latencies)
	Auditory pathways and Brain function	
	• Headphones / Earphones	• ERS (Auditory Latencies)

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c). Clinical equipment: In order to include reliable systems of reference, clinical and highly specialized biomedical equipment were also included in the project such as Defibrillators, a Respirator, Training/Test systems, Skill-trainers, Simulators of physiological parameters, electrical safety analyzers, Biochemical analysis systems, Evoked Response equipment (ERS), and Biochemical and Gas analyzers. Table 3 shows the name and purpose of the Clinical equipment considered for the LIBMM.

Table 2: Description of the General-purpose equipment considered for the LIBMM. Classification, name and purpose of all-purpose equipment for electronic measurement and computer tools (software and hardware).

Classification	Name	Purpose
Electronic measurement		Providing electronic tools to create and evaluate biomedical systems
	• Function generator	
	• Digital oscilloscope	
	• Multimeter	
	• Power supply	
Computer tools		Providing hardware / software tools to create and evaluate biomedical systems by:
	• Computer	• Supporting software and hardware for data processing, and Internet access
	• Software to acquire and process signals	• Developing algorithms to acquire and process physiological data.
	• Software for Virtual Instrumentation	• Developing Virtual Instruments and Graphical Interfaces
	• Software for Anatomy and Physiology	• Increasing theoretical knowledge about Anatomy and Physiology
	• Data acquisition card	• General acquisition of Biomedical signals
	• Printer	• Printing codes or signals from specific applications

Table 3: Description of the Clinical equipment considered for the LIBMM. Name and purpose of the stimulators, life supports equipment, training and test systems, laboratory analysis systems, and other highly specialized equipment.

Name	Purpose
Clinical equipment	Providing actual, reliable, and commercial standards for students testing their projects by:
Stimulators	
• Defibrillator	• Studying characteristics and function of systems for cardiac function
• Electric stimulator	• Generating electrical stimulus (rate, duration, amplitude, phase, polarity)
Life supports	
• Respirator	• Studying characteristics and function of systems for respiratory function
Training / Test systems	
• Skill-trainer	• Simulating normal and pathological ECGs
• Training / Test Lung	• Simulating human lungs in normal and pathological conditions
• Patient simulator	• Simulating electrical signals for ECG, temperature, pressure and respiration
• Electrical safety analyzer	• Evaluating electrical parameters in medical equipment
Laboratory analysis	
• Biochemical analysis system	• Measuring Electrolytes and Metabolites in blood
• Blood gas and biochemical analysis system	• Measuring Oxygen saturation, Electrolytes, and Metabolites in blood
Other systems	Transduction, conditioning and processing of physiological data by detecting:
• Evoked Response system	• EMG / MUAP, MCV, SCV, F-WAVE, H-REFLEX, ABR, MLR, SVR, ECOCHG, PR-VEP, LED-VEP, EXT-VEP, ERG, EOG, Cognitive Potentials
• Pneumotach air flow system	• Lung volume and flow air
• Pulse oxymeter	• Non-invasive pulse waveform, SpO2, and pulse rate
• Gas analyzer	• O2 and CO2 concentration levels in expired gases
• Eye potentials system	• ENG, EOG
• Invasive pressure transducer	• Invasive pressure

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3. Laboratory organization: Six workstations were constructed and placed in the laboratory, each one with electrical grounding and Internet access. Each workstation (WS) was designed to enclose equipment for: (a) electronic measurement, (b) conditioning and acquisition of bioelectric signals (basic systems, electrodes and amplifiers), (c) computer tools and, (d) a small and movable bed to ensure patient comfort during the data acquisition process. Additionally, the attributes of each WS can be changed through the substitution of transducers and amplifiers according to the objectives and approaches of the laboratory experiment. For example, if students wanted to measure the electromechanical cardiac activity, they could change some bioelectrical transducers and amplifiers for those that measured the PCG and the Peripheral Pulse wave.

4. Improvement and development of experiments: Once the project was undertaken, the process of improving the already set of experiments and the development of new ones started. The purpose of this action is that the *students can participate actively in the laboratory*, whereas each teacher is free to choose the tools or consent students to choose them according to the course approach and their personal interest. In this stage, students or teachers would have the possibility to decide: (a) developing analog, digital or virtual instruments, even a hybrid one; (b) programming graphical interfaces to connect clinical equipment and computers; (c) testing and characterizing transducers or equipment, commercial or constructed by students; (d) training with clinical systems to acquire experience and, (e) studying physiological systems by acquiring data from humans or by using specific software.

Results

Thanks to the support received from the UAMI and to the participation of students and faculty, it can be said that the objective of the LIBMM has been reached, at least for an initial level. The LIBMM has a wide number of current tools, and makes it possible for students to face different problems, evaluate and propose solutions using different approaches and technologies.

The number of units of equipment in Table 1 was increased to six, and new technologies, from NK and BS, have been added to the available experimental equipment. Nowadays it is possible for six teams to work simultaneously during the experimental sessions, and more students can participate in the experiment. Students can also work with at least two modern technologies, and depending of the objective of the experiment, one or two technologies can be chosen.

Figure 1 shows some transducers mentioned in Table I for non-invasive measurement of PCG, Cardiac Output, Peripheral Pulse wave and Respiratory curve. In all cases the reader can see both technologies, NK and BS. Figure 2 shows the corresponding NK and BS amplifiers for measuring PCG, Cardiac Output, Peripheral Pulse wave and Respiratory curve. The reader can see that all of them can be put together to create a specific system for measuring physiological signals.

Figure 1: NIHON KOHDEN (top) and BIOPAC Systems Inc. (bottom) transducers for measuring physiological signals. From left to right: (a) PCG, (b) Cardiac Output, (c) Peripherial Pulse wave and, (d) Respiratory curve.

Figure 2: NIHON KOHDEN and BIOPAC Systems Inc. amplifiers for measuring physiological signals. From left to right: (a) PCG, (b) Cardiac Output, (c) Peripherial Pulse wave and, (d) Respiratory curve.

Related to Table 3, figure 3 shows the clinical equipment bought for direct measurement of Electrolytes / Metabolites in blood Roche Diagnostics Corporation™. This equipment makes it possible to characterize some non-invasive instruments, or study some biological systems by measuring their biochemical behavior.

Regarding the laboratory organization, each WS is independent, has a wide number of modern tools, and makes it possible for students to face different problems, evaluate and propose solutions using different approaches and technologies. This distribution have also reduced the time for setting up the experiments, and have increased the useful life of the equipment. Figure 4 shows the front view of a WS once it was installed and outfitted with equipment from Tables 1 and 2. From left to right you can see: (a) the electronic measurement equipment, (b) a printer, (c) a basic system composed by a NK polygraph, four NK bioelectric amplifiers, and a MP150 system from BS, (d) a computer with AcqKnowledge™ (a software to control the MP150 module), MATLAB™ (to acquire and process signals), LabVIEW (for Graphical interfaces and Virtual Instrumentation), A.D.A.M software™ (for Anatomy and Interactive Physiology), and an all-purpose Data acquisition card from National Instruments™.

Figure 3: Clinical equipment for blood measuring Electrolytes/Metabolites from Roche Diagnostics Corporation.

Figure 4: A workstation outfitted with equipment from Tables 1 and 2. From left to right: (a) electronic measurement, (b) printer, (c) basic system composed by a NK polygraph, four NK bioelectric amplifiers, and a MP150 system from BS, (d) computer with data acquisition and processing software.

The LBIMM equipment gives students the chance to work with diverse instrumentation; they can practice with Clinical equipment, make it and/or characterize transducers and/or amplifiers, acquire physiological signals and process them to obtain non-invasive information about the cardiovascular, respiratory, nervous, cerebral or muscular condition. Figure 5 shows the LIBMM, two workstations and some clinical equipment: two Defibrillators from NK, two Skill-trainers from Laerdal™, and a Respirator from Bird Products Corporation™.

Students and faculty work has been so important; some of the most important projects have been focused on virtual instrumentation, either to adequate technology or to create software for acquiring and processing biological signals [3, 4]. Senior students have developed user manuals, manuals for experimental work [5], evaluated the technologies in the LIBMM [6], or created specific courses to train junior students on practical subjects.

Figure 5: The LIBMM, two workstations and some clinical equipment: two Defibrillators, two training systems, and a respirator.

Figure 6 shows a Virtual Instrument (VI) that was programmed to remotely control the Neuropack Sigma, a clinical system for measuring Evoked Response (ERS) from NK. This VI makes it possible to measure Auditory, Somatosensorial and Visual ERSs, no matter the user experience, because the VI has two operation levels, basic and advanced. Once the Neuropak has processed the ERSs, the VI transmits the information from the Neuropack to a computer, so it is possible to display, print or store data each time the user wants [3]. This example shows the Medium Latency Auditory responses obtained by the VI.

Figure 6: A Virtual Instrument that a student programmed to remotely control the Neuropack Sigma, a clinical system for measure Auditory, Somatosensorial and Visual Evoked Responses. Reader can see the Medium Latency Auditory responses obtained by the VI.

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Figure 7 shows a monitor for fetal heart rate that a student created by using a LabView-Matlab program. This VI acquires and processes the fetal PCG (fPCG) displaying, almost on-line, the Cardiotachograms (CTGs) generated by detecting the cardiac sounds, S1 and S2. It also stores information and provides the possibility to manually correct the CTGs generated [4].

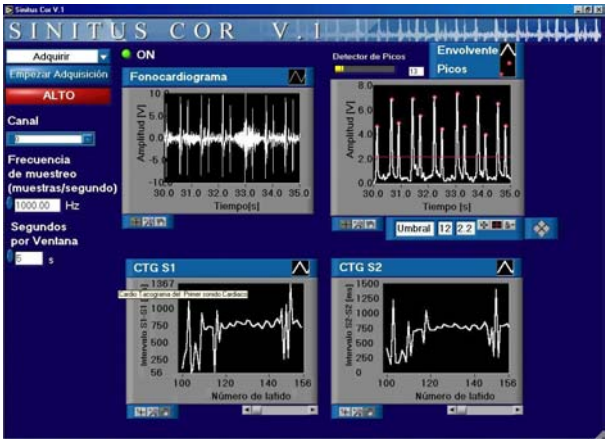

Figure 7: A Virtual Instrument for monitoring fetal heart rate that a student created by using a LabView-Matlab program. From left to right and up to down: fPCG, envelope and time references detected from each cardiac sound (S1 and S2), the CTG associated to S1 and the CTG associated to S2.

Figure 8 shows some junior students during a LabView training course that was recently imparted by students from the Biomedical Engineering Postgraduate Program at UAMI.

Figure 8. Junior students during a LabView training course, recently imparted by students from the Biomedical Engineering Postgraduate Program at UAMI.

Discussion and Conclusions

After four years of operation it can be said that the Laboratory for Biomedical Instrumentation (LIBMM) has produced promising results. The equipment gives students a wide number of alternatives to work with; more of them can spend their practical sessions either designing electrical/electronic circuits and computer software for medical instrumentation or training with software and clinical equipment. The laboratory organization makes it easy to set up the experiment because it is not necessary hooking up the equipment each time. The equipment now is more accessible and its life-cycle has been increased.

However, there is still much work to do. The outfitting process will continue making necessary to develop new experiments and user manuals. It is also necessary to improve the laboratory administration, promote its use, and get a quantitative evaluation of its performance. In order to pursue these goals, it has proposed a network installation, the development of a dynamic WEB site [7], and periodic meetings where faculty propose new projects to encourage senior students to perform their terminal project or community service in the laboratory.

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