Virtual Instrumentation Based Equipment for Bio-medical Measurements

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Abstract* – This paper presents our equipment for bio-chemical measurement, designed for monitoring the functional parameters of the persons undergoing effort tests. This equipment, based on a virtual instrumentation, has more functions: the acquisition of biological signals from the participant running in the effort tests for the anaerobic threshold; the hardware and software configuration of the equipment; the setting of maximal parameters depending on the type of test; the processing of the acquired data in real time for various alarms, end points and displaying this data on the screen; the transmission of the acquired signals in real time or of the stored ones to a computer for further analysis. This provides a useful and elegant tool for both hardware and software development and for daily usage for research or stress tests regularly carried out in the Cardiology or Sports Medicine Departments of Hospitals.

Keywords: *bio-medical, virtual instrumentation, anaerobic threshold, research tool.*

I. INTRODUCTION

Biomedical engineering is one of the fields in which virtual instrumentation has penetrated rapidly and strongly, in both research endeavors and current use equipments. An important note must be taken towards the fact that virtual instrumentation will not replace traditional instruments entirely, especially in highly specialized domains. In the case of many applications, combined solutions are preferred, based on both measuring techniques and providing the advantages stemming from these.

Virtual instruments use the open architecture of regular computers, including their processing speeds, memory and display capabilities together with inexpensive interface boards, connected to the appropriate bus, and the renown connectivity of such computers for creating equipments that are efficient, re-usable and re-configurable. The end result is a piece of virtual equipment whose performances, uses and configurations are set and defined by the user. The advantage of virtual instruments over traditional instruments will continue to rise due to fast developments in the world of PC tehnologies. The major benefit resides in the increase of performance, coupled with a sharp decrease in implementation costs. A further characteristic of virtual instruments that needs to be underlined is the possibility to use the same computer for different virtual instruments (of course, with the appropriate interface), and to transfer data acquired with one such instrument to the other, at the software level.

The emergence of this concept was chiefly determined by the intrinsic limitations of any closed-type architecture, represented in the case of biomedical engineering by classical box-like instruments. The functionality of the latter is defined by the producer, limiting both the possibilities for expanding the diagnostic or intervention process, and the performance the user may desire at a certain point. The upgrading process, which in the case of computers is easy, cheap and accessible, can be difficult or even impossible for classical instruments.

Effort tests which monitor the anaerobic threshold require special pieces of equipment. They can be grouped according to their functionality, as follows:

- Equipment for generating effort
- Equipment for bioelectric measurements
- Equipment for biochemical measurements
- Equipment for storing, analysing and displaying data

The declared purpose of the research team was to develop and offer physicians (cardiologists, in particular) a useful piece of equipment, which should be easy to use and which should allow:

- effort-testing of patients with cardio-vascular conditions
- effort-testing of patients in recovery after a coronary incident
- effort-testing of athletes (in search of cardio-

vascular issues that might affect their performance and health).

More specifically, the team aimed at top performance in the field of effort testing using non-invasive medical techniques.

II. DESIGN AND IMPEMENTATION

The project of the equipment was designed using the virtual programming environment LabView, NI-DAQmx 8.7.1 software and USB-6008 module from National Instruments. The block schematics are shown in Figure 1., where:

- The $\%CO_2$ CAPNOLYSER is a continous respiratory gases concentration analyser, with a measuring area for CO_2 concentration of 0 to 10%, corresponding to an output voltage of 0 to 1V.
- The WIRELESS ECG is a Gasemann ECG.
- The treadmill is a custom made equipment, specially designed for stress tests. The stress tests protocols are resident in the treadmill memory and the desired one is selected via interface by the main program.
- The body monitor which measures the body temperature and skin humidity.
- The data acquisition system is created around a USB-6008 National Instruments USB module, driven by NI-DAQmx 8.7.1 software.

All these equipment elements are controlled using the LabView graphical programming environment, which yielded a performant and extremely user-friendly virtual instrument. The virtual instrument created in a LabView has several functional blocks corresponding to the implemented functions [1].

The first functional block is the signal acquisition block, for acquisition of biological signals from the participant: ECG, respiratory rate, CO_2 concentration in exhaled air, body temperature, skin humidity. This module uses the time multiplexing signals method with constant sampling rate. Taking notice that the widest band among the input signals is the one of the ECG – the maximum is 50 Hz – a sampling frequency of 100 Hz is completely between the boundaries set by the Sampling Theorem. For the ECG channel: selecting the desired ECG derivation, filtering the signal [7], [8], (so that the noise created by the power supplies - 50Hz and by the muscles does not interfere with the signal), the detection of the QRS complex and the calculation of the HR;

For the $\%CO_2$ Capnolyser: filtering of the input signal, the detection of the local maximum values (END TIDAL) and the minimum ones (INSPIR) and the calculation of the respiratory rate RR. The cardiac anaerobic threshold is detected from the filtered peak signal, using the correlation between HR and the peaks of the seven points Givens polynomial interpolating signal technique; For the body parameters like temperature and skin humidity, the measured values came from a digital thermometre and humidity sensor.

The second functional block is destined to save the acquired data in a special file, which can later be accessed in order to process the data.

The third block has the purpose of real time data processing. This includes also setting of maximal parameters depending on the type of effort test [3]. A part of the LabView program for third block is shown in Figure.2.

The forth block has the function of displaying the data acquired 'on-line' on a screen, the main window is shown in Figure. 3, and also of identifying the moment for ending the procedure, as a result of the effort test by determining the anaerobic threshold

The fifth functional block is created for interfacing with the treadmill device. There are two kind of controls, one digital for a custom made treadmill, for command of the velocity and slope channels, and another for a standard treadmill, an electrically-insulated standard serial interface (RS232c), both for adjusting the treadmill parameters in correspondance with one of the chosen standard protocols for stress tests [5]. These parameters also help determine the work rate generated by the patient during the effort test.

The result was an electrically isolated equipment, relating the patient, a part of which is shown in Figure. 4, to be used for data acquisition from a wireless ECG, from a CAPNOLYSER spectrometer (for determining CO_2 concentration) and from/to a treadmill used in the effort test.

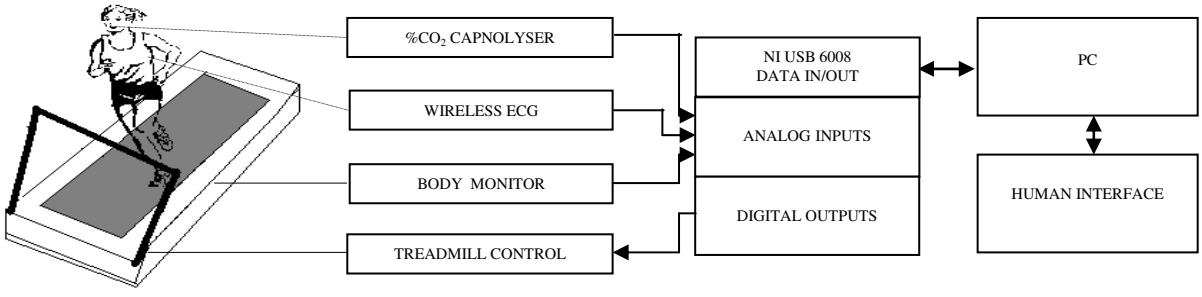

Figure 1. The block schematics of the Virtual Instrumentation Based Equipment

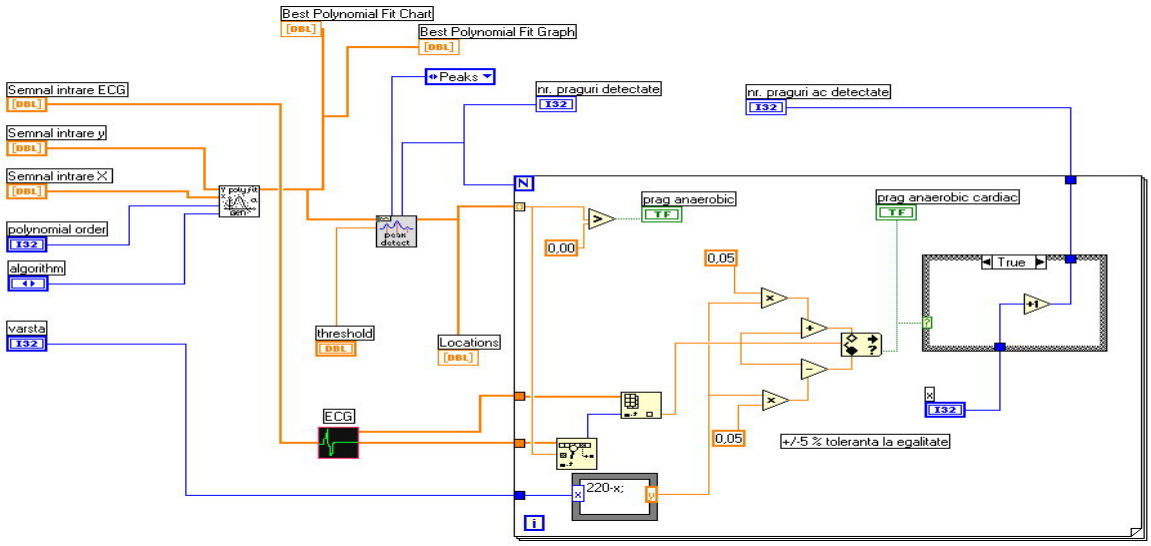

Figure 2. LabView program for real time data processing block, with setting of maximal parameters depending on the type of effort test.

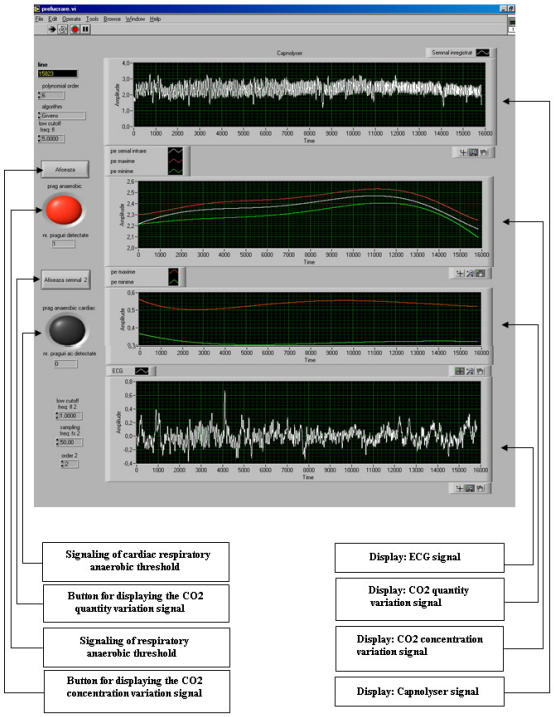

Figure 3. The main window, the front panel, of the Virtual Instrumentation Based Equipment

The detection of both respiratory anaerobic thresholds and cardiac anaerobic threshold (anaerobic threshold of the cardiac muscle) is carried out, according to [2], only from the End-Tidal component of the input signal, because it gives a more precise indication on the effort of the participant to the effort test, through the CO_2 concentration measured at the end-tidal breath [4].

One of the advantages of using the LabView graphical programming environment [6] is that the "front pannel" of the instrument is customisable regarding the end user's whishes and purposes.

Developing this equipment on the basis of functional blocks has led to the possibility of performing changes to the program rapidly and easily, depending on the specific user and application requirements, providing the foundation for further projects.

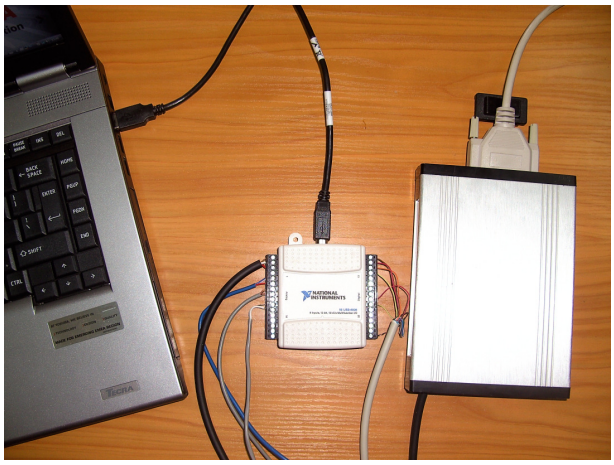

Figure 4. National Instruments USB-6008 module and part of the equipment hardware

III. CONCLUSIONS

This Virtual Instrumentation Based Equipment for Bio-medical Measurements provides a useful and elegant tool for both hardware and software development. The emphasis on designing and producing equipments specifically for this field is motivated by the necessity of such technologies, which are secure and inexpensive, user-friendly and accessible to specialized personnel in both effort-testing laboratories in hospitals and sports clinics and centres, and can be implemented rapidly in the appropriate hospital departments

The instrument's interface is user-friendly and meets the needs and expertise of the medical staff, by mirroring other instruments used in laboratories or clinics. The interface displays all the acquired information from the patient and the hardware, making the task of comparing results much easier. By visually signaling the occurrence of the anaerobic threshold in real time, the equipment is very useful in effort-testing of patients with cardio-vascular conditions or patients in recovery after a coronary incident.

In the same manner, this equipment can be very useful in evaluatig the effort capabilities of the sports people, and for set a individual training program for each athlet to achive better performance.

The developed virtual instrument is a valuable asset for current usage for research or stress tests regularly carried out in the Cardiology or Sports Medicine hospital departments.

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