Measuring System with Compound Software Architecture for Measurement and Evaluation of Biosignals from Isolated Animal Hearts

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Abstract. *Biomedical measuring system for acquisition, processing and evaluation of ECG signal, blood and perfusion pressure and drug dosage is introduced. Mentioned signals are obtained during experiments on small animal hearts making use of a Langendorff setup. The USB powered system is conceived as a virtual instrument with an external measuring unit controlled by a microprocessor and connected to a host computer with running application software. The novelty of the approach presented is purposeful compound architecture of the application software. For real-time data acquisition graphical programming language LabVIEW was used, due to the offered possibility of easier parallelization of processes. For off-line biophysical parameter analysis MATLAB, one of the most widely used signal processing tool, was applied.*

Keywords: USB-based device, Langendorff setup, compound LabVIEW and MATLAB software architecture, biosignal processing, parallelism

1. Introduction

Software development is a time consuming process, especially in so sensitive field as medical sciences [1]. In order to dynamically respond to continual technological progress and to solve technical computing problems within few weeks or months, small scientific teams prefer LabVIEW or MATLAB instead of traditional programming languages like C, C++ or Java.

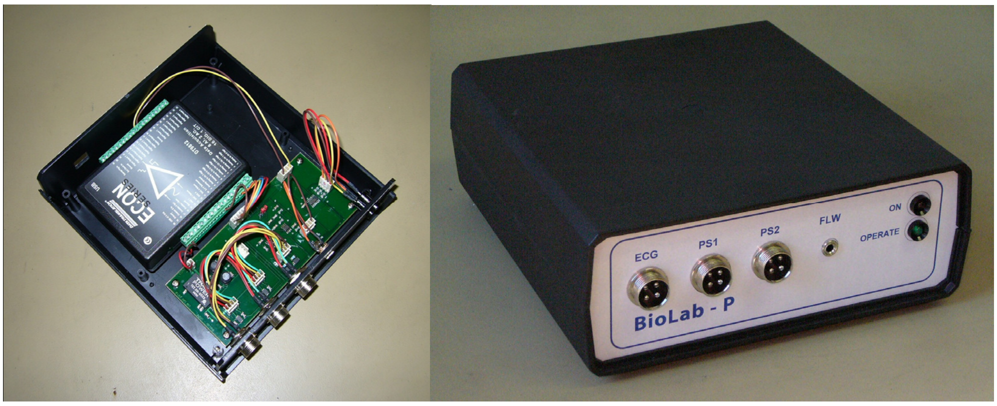
Measuring part of our application software is developed in graphical programming environment LabVIEW that has been widely adopted as the standard for data acquisition and instrument control [2]. Dataflow code developed with LabVIEW allows for automatic parallelization. Parallelism is important in advanced computer programs because it can unlock performance gains in comparison to purely sequential programs due to recent changes in computer processor designs [3]. Analytical part of our application software is developed in high-level technical computing language MATLAB and makes use of its signal processing toolboxes. Proposed software concept controls a communication between the measuring unit and the host computer, processes data stream during an acquisition, formats, visualizes and records measured signals and consequently realizes off-line processing and analysis of the measured signals.

2. Methods and results

Measuring system BioLab-P

Based on previous experience with BioLab series measuring systems [4], the USB powered measuring system BioLab-P was developed. The system consist of selected biosignals sensors, a signal conditioning module and a data acquisition module (Fig. 1a) that are placed in the measuring unit (Fig. 1b) and the host computer with a compound application software.

The BioLab-P measuring system allows to monitor and record one of two possible triples of biosignals. Either the electrocardiogram (ECG), left ventricular pressure (PS1) and drug dosage (DD) or ECG, PS1 and perfusion pressure (PS2) can be measured. The external sensors for sensing these four types of signals are part of the Langendorff experimental setup and their outputs are attached to corresponding connectors on the front panel of the measuring unit (Fig. 1). The Langendorff measuring system is suitable for „in-vitro“ investigation of isolated heart of small animals, such as rat, hamster or guinea-pig. It is used for evaluation of potential response of myocardial cells evoked by pharmacological stimulation. ECG signal is sensed by 2 specially designed monopolar Ag-AgCl electrodes. Peak-to-peak ECG signal amplitude is about 100 mV. Pressure signals (PS1 and PS2) are sensed by high sensitive pressure sensors PX181B-006G5V (Omega Engineering, Inc) that allow registration of pressure variances from 0 to 6 psi (0 – 40 kPa). Drug dosage signal (DD) represents an output TTL signal of a drop-type flowmeter. Each 5 ms wide TTL impulse corresponds to a drops volume of about 50 µl.



a) b)

Fig. 1. a) The signal conditioning module and the data acquisition module inside the measuring unit BioLab-P; b) The measuring unit BioLab-P

The signal conditioning module and the acquisition module are placed in a patient terminal box of small geometric dimensions (190x200x70 mm). The signal conditioning module adjusts electrical signals from the external voltage, pressure and flow sensors. Its outputs are through individual cables connected to the screw terminal of the Data Translation DT9812-10V acquisition module. The data acquisition module is an economy, multifunction mini-instrument that provides one USB connector, one 12 bit A/D converter with 8 channel multiplexer, input signal range of $\pm$10 V and programmable gains of 1, 2, 4 a 8 allowing more effective input ranges. The per-channel sampling rate is set to 1000 Hz in the application software. The data acquisition module is through a plug-in connector connected to an USB 2.0 port of the host computer. All electric circuits of the measuring unit are powered from the USB, what eliminates the need for an external power supply. Utilization of the USB interface facilitates bidirectional data transfer between the measuring unit and the host computer. Their mutual communication is managed by the application software.

Application software

BioLab-P application software consists of a measuring part and an analytical part developed in different programming languages regarding their suitability.

The measuring software is intended for real-time acquisition. It must process large amount of data within a few milliseconds. Our measuring program developed in LabVIEW (version 8.6) and destined for multicore computing systems can significantly reduce the execution time. Fig. 2 depicts the proposed modular multiple-loop application framework. The key features of this framework are four parallel loops running simultaneously and independently of one another. Messaging between these loops is accomplished using Queue constructs (Queue is the most commonly used messaging construct. It is an ordered set of elements [2] and in our application it serves as a FIFO buffer). Such parallel processing algorithm helps to divide processor usage among multiple cores [5]. In Fig. 2, the Data Acquisition Loop continuous to acquire data even if there is a delay in any other loop. The extra samples are simply stored in the FIFO in the meantime.

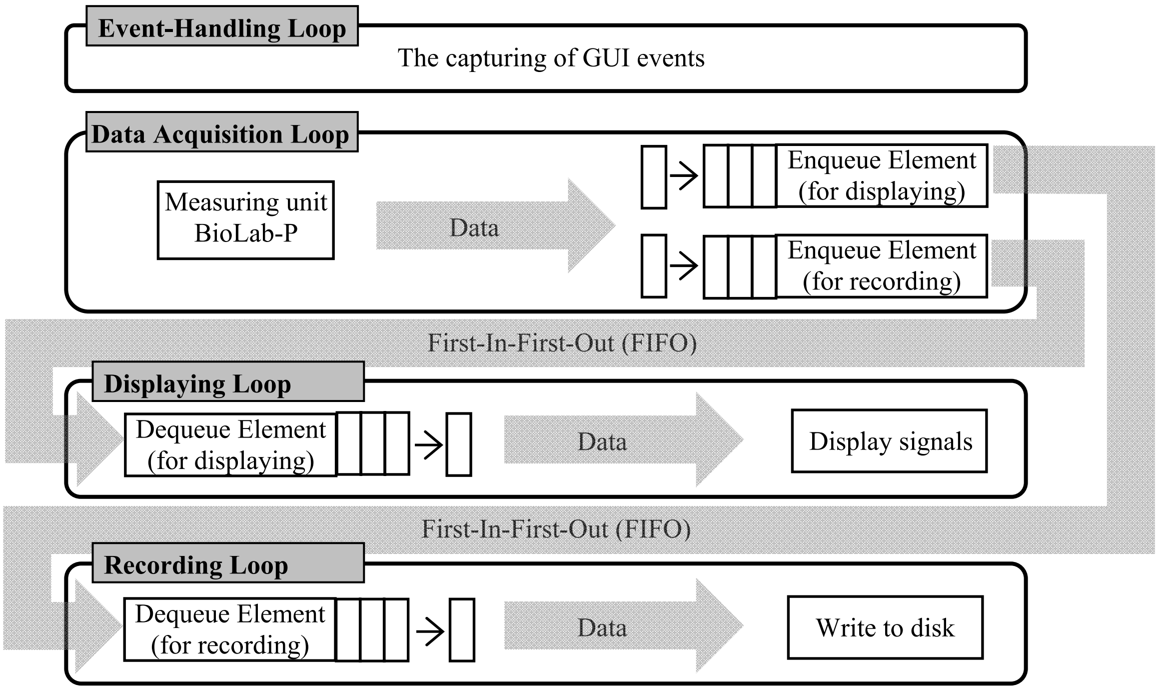
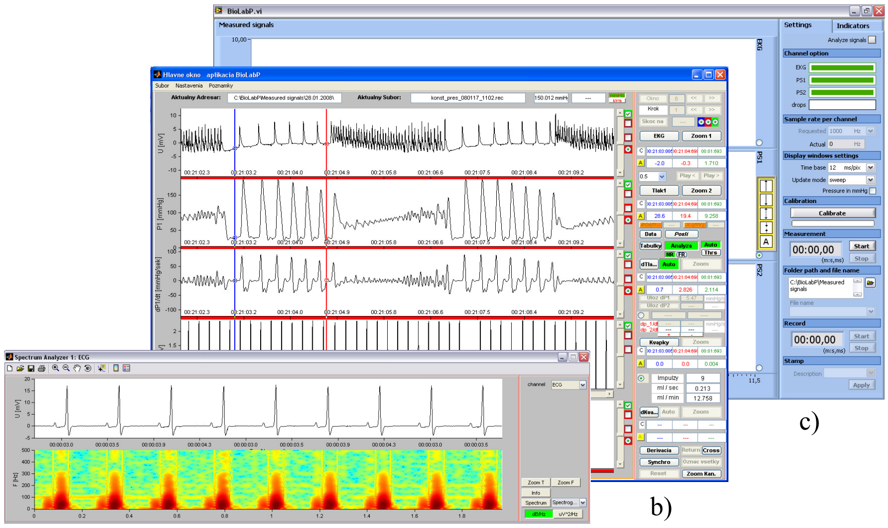


Fig. 2. A block diagram of modular multiple-loop application framework of the proposed measuring application. The diagram consists of the Event-Handling Loop for processing GUI activity, the Data Acquisition Loop for acquisition of sampled data from the acquisition unit, the Displaying Loop for visualization of measured biosignals, the Recording Loop for saving row data to disk and the queue-based messaging scheme that accomplishes synchronization and transmission of data between the loops.

Communication over the USB port is based on a DLL that supports Data Translation's DT9812-10V acquisition module. DLL functions are fully compatible with DT-Open Layers^{TM}, a set of standards for developing integrated modular application programs under Windows [6].

Using the GUI of the measuring software, the user can set e.g. the triple of measured signals, a time base rate, an update mode, or can modify the gain of amplifiers for optimal signal resolution and appropriate visualization on the computer screen. There is also a possibility to save all signals and eventually also their descriptive stamps on a hard disk.

The real-time data acquisition is followed by the off-line data processing and evaluation. Relevant application software is developed in MATLAB (version 7) and includes simultaneous tracing of selected signals, zooming, filtration by finite impulse response type filters, searching for defined type of events in the time domain, automatic computation of 28 parameters for each signal (e. g. number of drops, number of QRS complexes, heart frequency, number of extrasystoles, time derivation of signals), transferring of requested group of parameters to an Excel sheet, spectral analysis of the signals (e. g. computation of PSD, CSA, spectrogram), etc.



a) b) c)

Fig. 3. The screen shots of the BioLab-P user interfaces. a) The spectral analysis window with time-frequency analysis of an ECG signal; b) The main window of the analytical application with data loaded from experiments; c) The part of the main window of the measuring application.

3. Discussion and conclusion

The measuring system BioLab-P in conjunction with existing experimental setup represents a low cost, versatile solution for pharmacological researchers investigating animal hearts following drug challenges. Modularity of the whole BioLab-P system enables to change partial hardware and software modules if more advanced tools will be available. After compilation, the BioLab-P application software can be deployed as a stand-alone application on any computer with Windows XP and later OS.

As CPU manufacturers have moved to new chip architectures with multiple processor cores on a single chip, parallel programming is rapidly becoming a necessity in order to make the most of the newest multicore processors. Advanced applications has to be optimized for these multicore processors, otherwise the expected increased performance will not be reached [7]. This is also the reason why the parallel application framework for the real-time processing was introduced.

Acknowledgements

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