DESIGN OF A MATLAB TOOLBOX FOR MECHANICAL MYO-TONOMETRY SIGNALS PROCESSING, ANALYZING AND VISUALIZATION

Ivan Vladimirov Rachev[1], Galidia Ivanova Petrova[2]

[1]Dept. of Optoelectronics and Laser engineering, [2]Dept. of Electronics, Technical University – Sofia, Plovdiv branch, Tzanko Djustabanov 25, 4000, Plovdiv, Bulgaria, phone: +359 32 659 576, e-mail: ivr732@abv.bg, gip@tu-plovdiv.bg

Mechanical myo-tonometry is a promising method for performing biomechanical diagnostics on functional state of skeletal muscles. The method is based on recording and analyzing the signals produced from investigated muscle in response of short mechanical impact. In this paper a MATLAB Toobox for processing, analyzing and visualization of mechanical myo-tonometry signals is presented. It is designed to work together with special purpose ADC module and to give convenience to medical doctors in calculation the characteristic muscle parameters, archiving the results and their statistical processing. The graphical design and some special options like dc-level removing, digital filtration and specifics in parameters calculation are discussed. The proposed Toolbox could be used in medical practice, in research and educational areas.

Keywords: biological signal processing, digital filtering, MATLAB Toolbox, user-friendly graphical interface

1. INTRODUCTION

The review of the references shows that mechanical myo-tonometry (MMYOTON) is a promising method for development of new research of skeletal muscles and their functional state [1, 2]. The main principle of MMYOTON is to record the resulting signals produced by investigated muscle in response of short mechanical impact. For analyzes the three signals are important – the original of mechanical movement (***s***) signal, the velocity (***v***) signal and the acceleration (***a***) signal. These signals look like damped oscillations and from their parameters the characteristic muscle parameters like muscle frequency, elasticity and stiffness could be calculated. It is necessary to be accumulated enough quantity of these data in order to obtain statistical information about the functional state (normal or pathological) of the investigated muscle.

In a simple arrangement, for registration of muscle response the conventional three-channel ECG instrument is used. In this case, the manual determination and processing of signals parameters are very time consuming, boring and not enough accurate. To overcome the pointed drawbacks, a MATLAB Toolbox is proposed, designed especially for MMYOTON signals processing, analyzing and visualization.

2. PROBLEM STATEMENT

The proposed MATLAB Toolbox is designed to work together with special purpose external ADC module for MMYOTON signals processing and to give convenience to medical doctors in calculation the characteristic muscle parameters, archiving the results and further statistical processing.

The main requirements for the design of the Toolbox could be specified as follow:

- to be able to read the multiplexed digital data from external special purpose module ADC for mechanical myo-tonometry processing and discretization, via RS-232 interface;
- to be able to save the received data in file and read them later;
- to visualized data, received (raw) or saved in a file;
- to be able to apply digital filtration on received signals, when it is necessary in order to reduce the influence of internal and external interferences;
- to be able to determine the specific parameters of the recorded signals in purpose to calculate the characteristic muscle parameters;
- to have a user friendly interface, because it will be used by medical doctors.

The described features of the designed Toolbox are discussed and recommended from the academic staff at Department of Physiology in Medical University of Plovdiv. Their interest of having a convenient tool for analyzing and processing mechanical myo-tonometry signals is related to their intention to continue the started research in this field further.

3. Graphical Design of User Interface and Work Options in the Toolbox

The Toolbox window, shown on fig. 1, is designed using MATLAB procedures for creating graphical user interface [3]. It contains three panels. The first one (marked by 1 on the figure) is designed to present text messages and calculated results. The second panel (marked by 2 on the figure) is designed for graphical visualization of the signals. The third panel (marked by 3 on the figure) contains tools (buttons and sliders) for optional signal processing.

To start reading data from external ADC module, connected to the serial port of PC, it is necessary to press button <Connect>. A time-out of 30 sec is envisaged for data receiving. The duration of the time-out is determined on the bases of the defined 11 sec time interval for one measurement. Considering that the period of mechanical impacts on the muscle is approximately 1 sec, there are about 10-11 muscle responses in one record, from which the doctor can make the proper choice. If there are no data received during this time interval a reminding massage appears in the text panel. Otherwise, if the data are received correctly, the graphics of the signals are visualized in the graphical panel. The scale in the X-axis is in msec and in Y-axis - in the received from ADC module digital values. The raw signals received from the external module have a dc-level positioned in the center of the dynamic range of the ADC as a result of schematic realization. This dc-level does not represent the real physical situation for recorded signals (muscle movement, velocity and acceleration) and has no relation to the interested characteristic muscle parameters. Therefore, in graphical visualization and parameters calculation the dc-level is removed. However, when saving data the removed dc-levels are recovered in order to have compatibility with other MS programs. In this way there is no matter if the data are read with the proposed Toolbox or with other MS programs.

After the signals are visualized on the graphical panel the program suggests two possible options: to apply filtration, if the doctor considers it is necessary, or to go for calculation of the results.

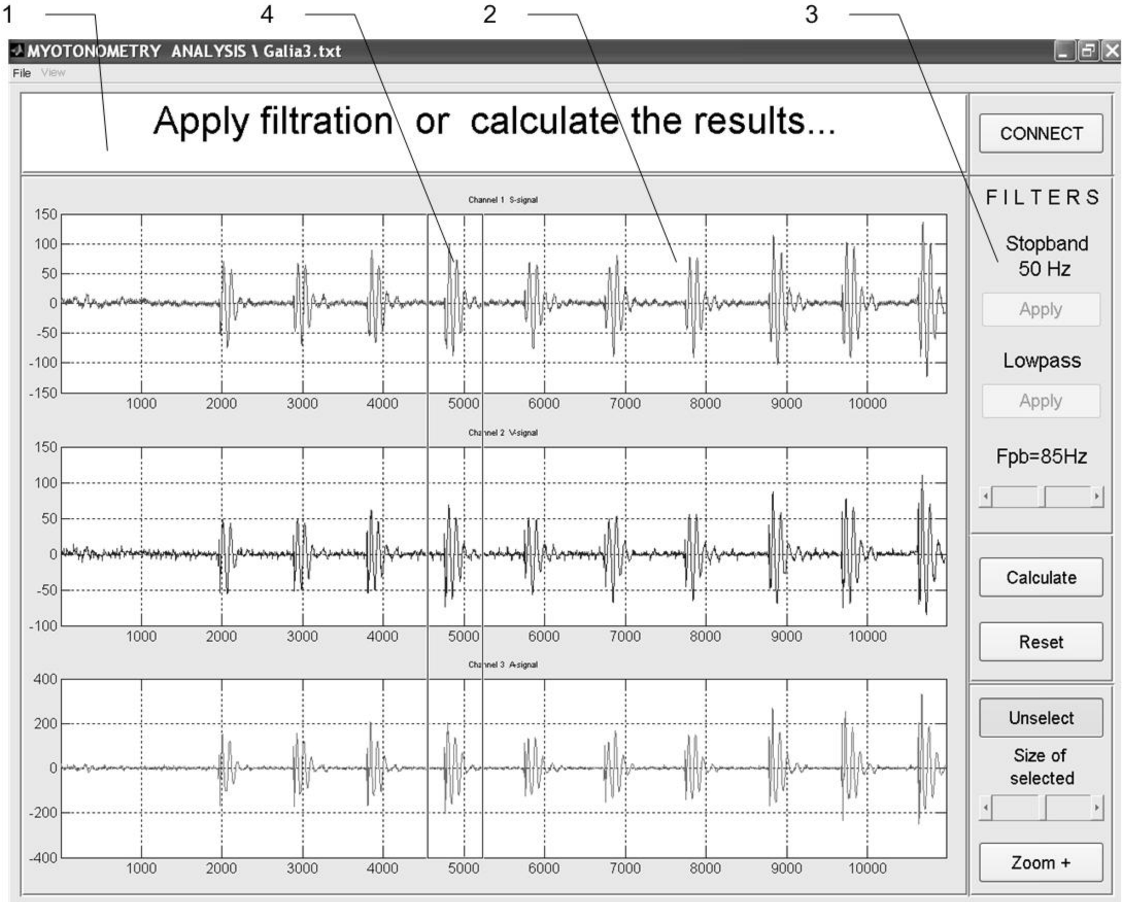

Fig.1. Graphical interface of designed MATLAB Toolbox

As a possible option, in the proposed Toolbox two types digital filtrations are envisaged and realized. They are designed using Signal Processing Toolbox for MATLAB [4] in purpose to decrease the influence of the internal and external interferences coming from movement artifacts, power supply, electromagnetic waves, etc. The first filter is a stop-band for 50Hz, while the second is a low-pass filter with cut-off frequency (Fpb), which could be changed in a range of 50 – 120 Hz by the corresponding slider tool. Either filter is designed as a fourth-order Butterworth approximation of its transfer function.

If anyone of digital filtration is applied and data for filtered signals are saved in a file, the next time after opening this file the corresponding filtration will not be permitted. This is necessary in purpose to have coincidence of the results every time when this file is used. The last restriction is realized because filtration has some influence on the calculated results, although not in a so large scale.

Before going to the procedure for calculation of the characteristic muscle parameters, it is obligatory to select a preferred area from the whole signal, called ‘region of interest’ (ROI), wherefrom the signals parameters will be determined. Then on the graphical panel of the screen the rectangle appears as illustrated by marker 4 in fig.1. The width of ROI must be selected according to the specific of the particular signals in such way that only one damped oscillation to be inside. The position of ROI must be selected so that the muscle response to be approximately in the center. The next step is zooming of the ROI by pressing button <Zoom+>.

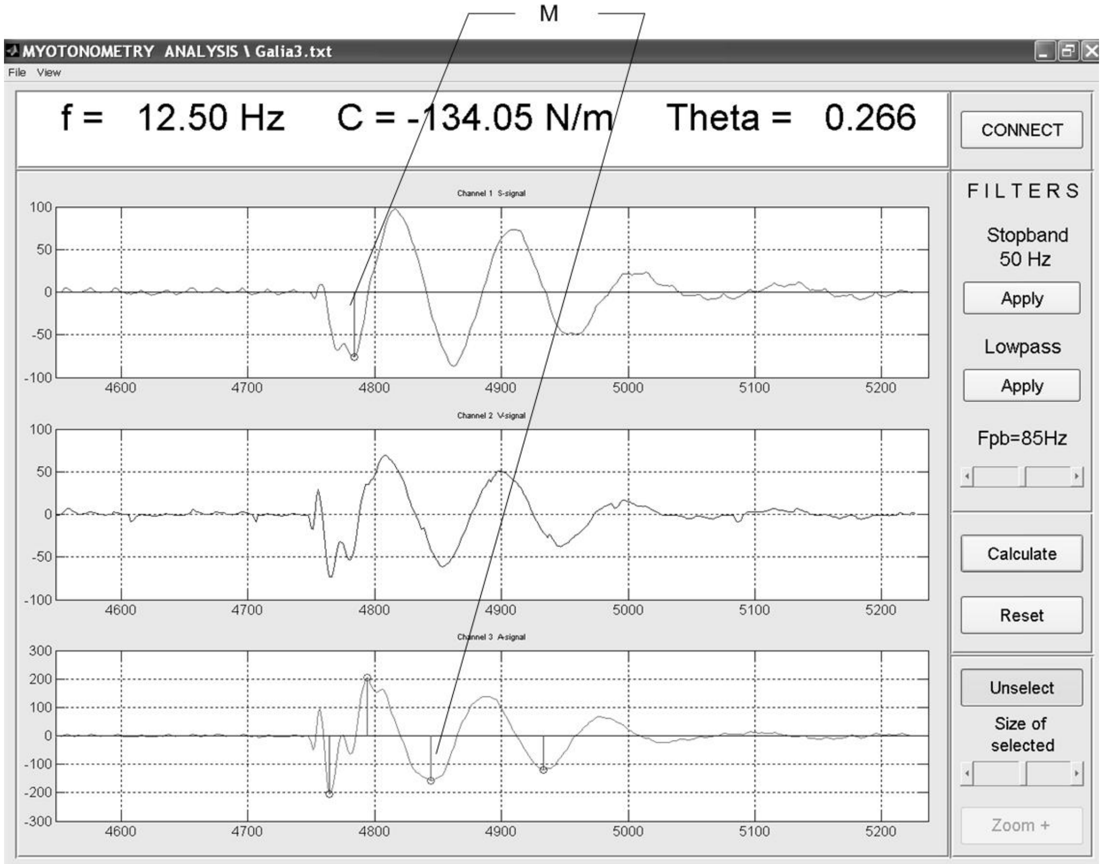

Fig.2. An example for signal parameters determination and calculation of f, C and Theta.

When activating button <Calculate>, the program goes in the procedure for determination of signals parameters. If one of the above mentioned conditions is not meet, a massage with particular recommendations about ROI re-selection appears in the text panel. The result of parameters determination procedure is visualized on the graphical panel, as it is illustrated on fig.2 with markers (M), positioned on the signals. It is worth to notice, that the shape of the recorded signals is not determined and depends on the experiment conditions and the functional state of the investigated muscle. Therefore, it is possible the results of the procedure for signals parameters determination not to be satisfactory and acceptable for the medical doctor. This was the reason for inserting the markers on the signals. Then, it is the doctor decision how to proceed further: to select another ROI or to apply filtration.

The characteristic muscle parameters (like muscle frequency, elasticity and stiffness) are calculated according to the following equations [1, 2]:

(1) $$f = \frac{1}{T}[Hz],$$

(2) $$\Theta = \ln\frac{a3}{a5},$$

(3) $$C = \frac{m.a_{\max}}{\Delta l}[N/m],$$

where: f is the oscillation frequency of the tissue, T – the oscillation period in seconds, Θ is the oscillation logarithmic decrement of the tissue; a_3 and a_5 – the oscillation amplitudes (the third and fifth minimum) of acceleration (*a*) signal, m is the mass of the sensor in the testing end of myo-tonometer, a_{max} is the maximal amplitude of oscillation in (*a*) signal, Δl is the amplitude of the first minimum of the movement (*s*) signal.

The results for the calculated values of the above mentioned characteristic muscle parameters are displayed in the text panel – fig.2.

The presented MATLAB Toolbox allows saving data for recorded myo-tonometry signals as a text file (.txt) or as a standard MATLAB figure (.fig). The figure contains the values of calculated parameters and graphical presentation of the signals. Saving the data in figure format gives additional facilities for archiving and further statistical processing.

The designed Toolbox posses some additional features like visualization of one selected signal and processing of generated graphics (figures) with standard tools supported by MATLAB.

4. CONCLUSIONS

The presented MATLAB Toolbox is given for approbation from medical doctors in Department of Physiology in Medical University of Plovdiv. After collecting enough data and having impressions about the program possibilities it could be developed with some new features in accordance with the doctors' recommendations.

Another area of application of the Toolbox is in the educational process for the students in Medical University and Technical University of Plovdiv. It is a useful tool for demonstration of mechanical reaction of skeletal muscles for students in Medicine, from one side, and a good example about the principles, design and application of computer systems in processing of biomedical signals for the students in Engineering field, from the other.

The proposed Toolbox is easily integrated with the other Microsoft programs, which is useful for data archiving and for presentations of the research results.

5. REFERENCES

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