ANALYSIS OF BIOSIGNALS IN MATLAB ENVIRONMENT

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A subject "Biological signals" has been taught at the Faculty of Electrical Engineering of Czech Technical University in Prague for many years. The native and evoked biosignals are covered by the course. There are explained methods of their nature, methods of recording, processing and evaluation techniques. The complete explanation of the most important biosignals and signal processing techniques are presented during lectures for electroneurography, muscle origin signals (EMG, MMG), electrocardiography (ECG), magnetocardiography (MCG), phonocardiography (PCG), electroencephalography (EEG), signals in gastroenterology, in ophthalmology, otic signals, nystagmography, biosignals in obstetrics, etc.

The structure and program of the laboratory tasks has been changed recently in order to improve impact on students. Maximal employment of computers has been intended and the main goals of the computer labs exercises have been defined. During the laboratory seminars the students have to:

- Get to know well basic biosignals - their characteristics, spectra shapes, typical applications and practical needs of their processing and evaluation.
- Get to know basic algorithms for biosignal processing and
  Get to know their usage, limitations and programming - presumptions of correct usage, sensitivity, effect on signals, methods, problems with implementations, etc.

The main topics of biological signal processing and analysis included into the program of the seminars are:

- Acquisition and data sampling - effect on spectra
- Preprocessing – methods, conditions, undesired effects on signals
- Filtration – digital filters and their usage and properties
- Segmentation – extraction of the symptoms
- Important and characteristic patterns detection
- Transforms – usage for biosignal compression, visualisation and advanced processing
- Processing using models of the biological structures

Several important things have to be considered during preparation of computer aid education. In general there are three possibilities how to prepare the education and exercises. Each the possibility has several advantages and disadvantages. The possibilities are:

1. Usage of specialised educational programs. For each task has to be designed and developed a special software application. Advantages of this approach are

fastness of the demonstrations of the individual methods and the fact that the best results are provided due to the proper long-time development of the software. A simple usage can be a next advantage. But there is one cardinal problem. The student cannot directly work with the real data of biosignal, they cannot get to know them and their properties well because the data are inaccessible and hidden in the software. Also development of such a software is time demanding and not easy for the lecturers.

2. Usage of an environment such as MATLAB. The MATLAB environment allows easy data input without necessity of its programming, simple visualisation of input data and results (graphs) without complicated programming, simple programming of data processing algorithms, easy operation with vectors and matrixes and full support of complex arithmetic and advanced functions. The students have to program the biosignal processing algorithms and they have to work with the real signals. Even they can try to conduct any operation with the signals and they can experiment with them, what helps the students to learn all intended. The only disadvantage is necessity of learning a new MATLAB language, but according to our experience, students that have already absolved programming in PASCAL or C are able to use MATLAB sufficiently for the computer lab exercises after less then 2 hours of training.
3. Usage of a programming language such as C, Pascal, etc. There is also necessary to work directly with the data and there is a possibility to experiment with them. But considering the necessity of input/output procedures programming, presence of only very basic support of graphics and very uneasy mathematical programming, this approach is very time consuming, requires good students' experience in programming in the language.

Considering all the advantages and disadvantages the second approach employing MATLAB or similar mathematical environment seems to be the best. Therefore, the computer lab exercises of "Biological signals" are carried out in the MATLAB environment. All the topics deal with real biosignals. Education is conducted in a computer room with 12 PC computers. A net version of MATLAB program runs on a platform of Linux operating system.

Three examples of the concrete tasks are presented. The first one is very simple and serves as an educational tool for understanding correlation and autocorrelation. Students are given a real record of electrocardiographic signal (Fig. 1). They have to program algorithm of autocorrelation of this signal so that for example R-R interval could be evaluated. During the programming they face several problems, for example necessity of signal extension at the ends, effect of baseline

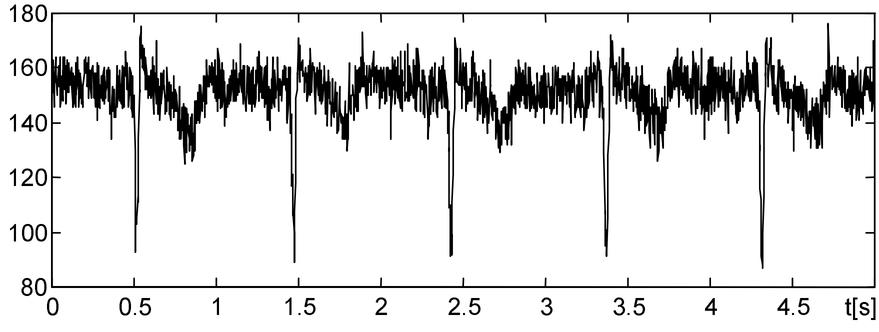


Fig. 1: Input signal - record of human electrocardio-graphic signal.

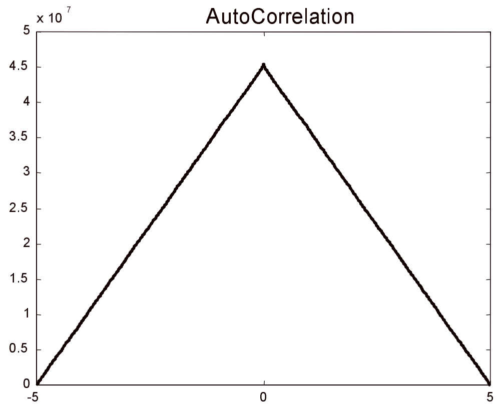
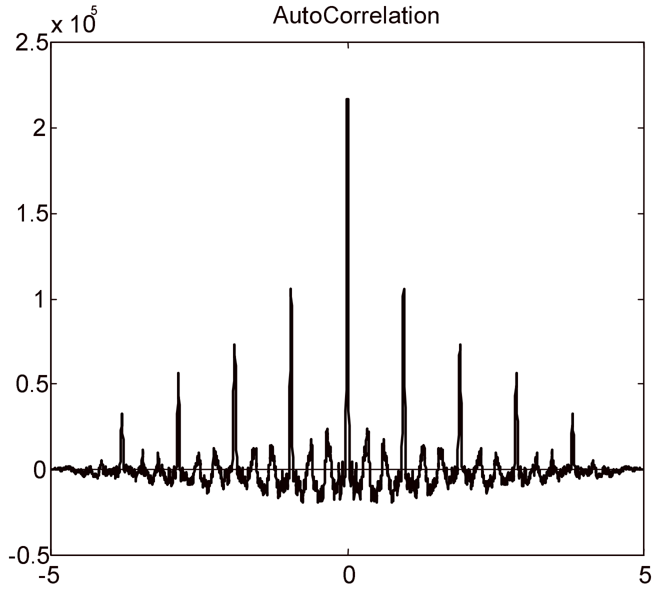


Fig. 2: Autocorrelation without baseline elimination.

Fig. 3: Final autocorrelation.



and its drift during computation (without its elimination the autocorrelation function is unusable (Fig. 2)), effect of filtration on the result (presented in Fig. 3).

The second example deals with the Hilbert transform that is useful during analysis of biosignals. The task is to create algorithm for associate signal computation and algorithm for signal envelope and phase evaluation. Students have to observe phenomena in spectra, problems with baseline and finally they try several applications on a real biosignal. First, they study and develop the algorithms on a artificial signal (a sum of two sine waves with different but close frequencies) leadind to envelope detection (Fig. 4). Then, they apply the written programmes to a ECG signal to compute its associate signal (Fig. 5) and to plot this associate signal versus the original one (Fig. 6) in order to visualise ECG signal by different way, result of which is similar to plot of vectorcardiograph.

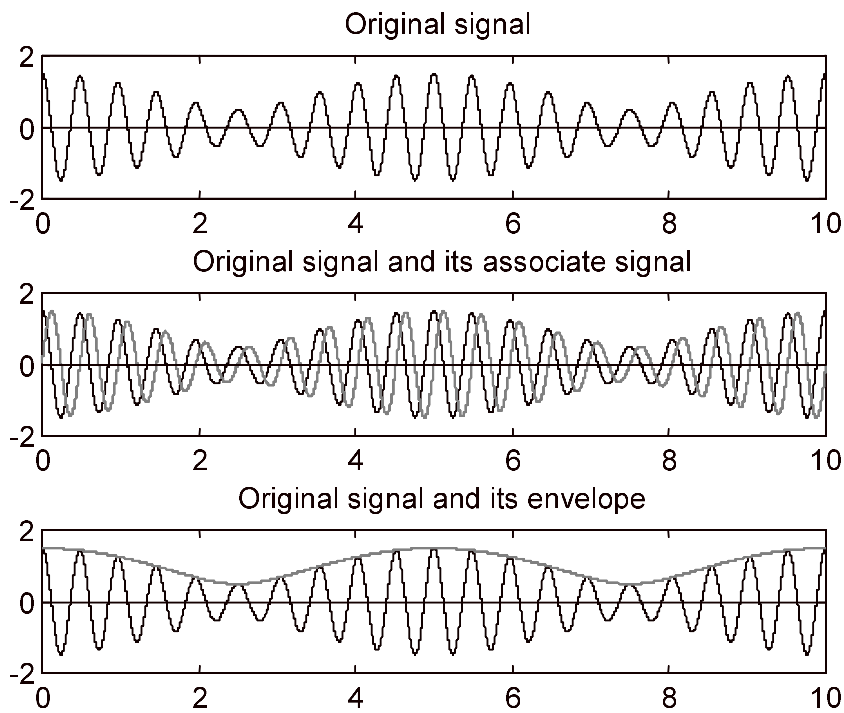
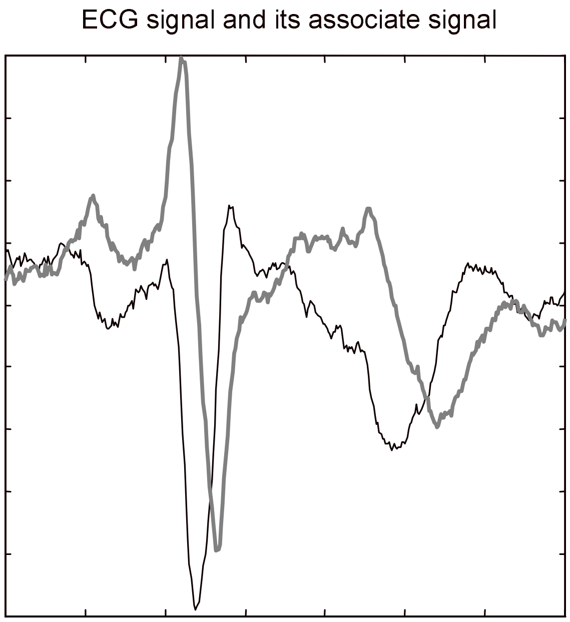


Fig. 4: Hilbert transform on an artificial signal: associate signal computing and envelope detection.



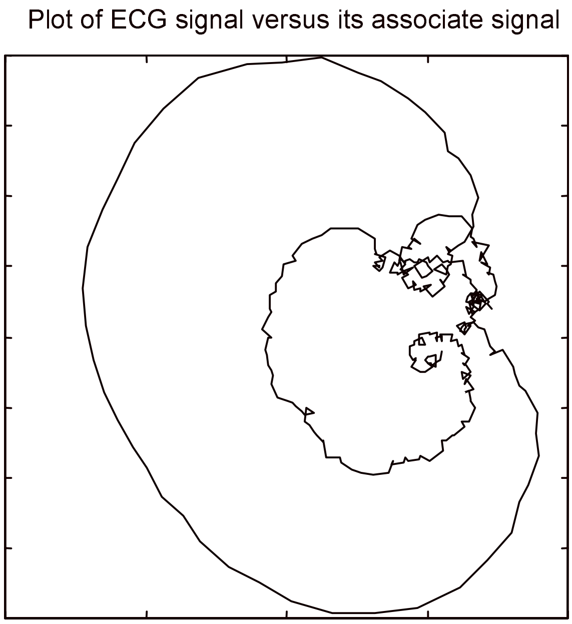


Fig. 5: Associate (grey) signal to the original ECG signal.

Fig. 6: Plot of ECG signal versus its associate signal.

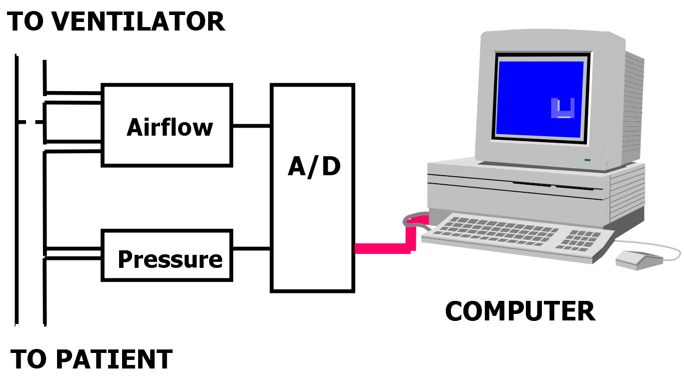


Fig. 7: Scheme of the HFOV monitoring system.

The last and the most complicated example of the lab exercises is modelling of the respiratory system during high frequency oscillatory ventilation (HFOV) and evaluation of the alveolar pressure course. Because of high ventilatory frequency during HFOV, which can be up to 60 Hz, the alveolar pressure is very different from the proximal airway pressure. For safe and efficient use of that unconventional ventilation technique the evaluation of the alveolar pressure is essential. Because the direct measurement is excluded, the only way of its determination is based on mathematical modelling of the respiratory system and computation of the alveolar pressure using the determined mathematical model. Two signals are given to students: records of proximal airway pressure and proximal airflow recorded in the airway opening during HFO ventilation using a special monitoring system [1, 2] the structure of which is in Fig. 7. They have also given a general structure of the

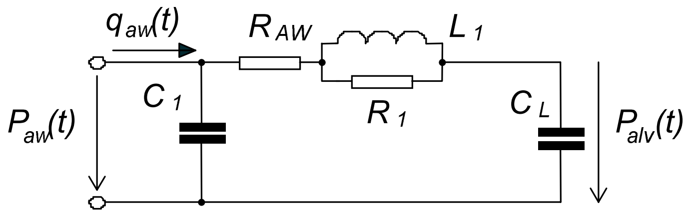


Fig. 8: Mathematical model of the respiratory system.

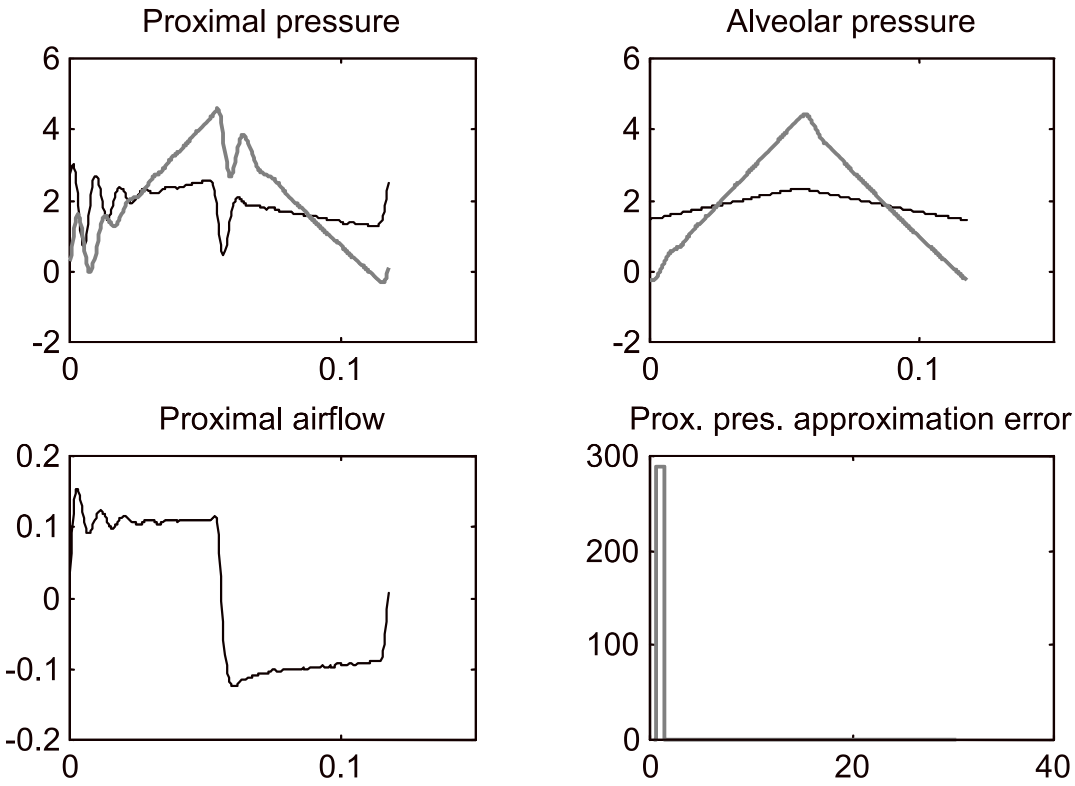


Fig. 9: First steps of iteration. Explanation in text.

mathematical model of the respiratory system for HFOV [3]. The first task is identification of the model parameters from the courses of proximal airway pressure and airflow. The input impedance function can be derived from the structure of the model. Students have to create an iterative algorithm for identification. Input impedance of this model describes a relationship between pressure and airflow (the same das electrical impedance between voltage and current in electric circuits). The written algorithm computes an auxiliary pressure (Fig. 9 a) - grey line) from the measured airflow (Fig. 9 b)) and input impedance of the model. The aim is to assure by automatic changing of parameters of the model, that the computed proximal airway pressure (Fig. 9 a) - grey line) and the measured proximal airway pressure (Fig. 9 a) - black line) are identical or the most similar. Than, the course of alveolar pressure can be computed (Fig. 9 c) - grey line) using a transfer function of the

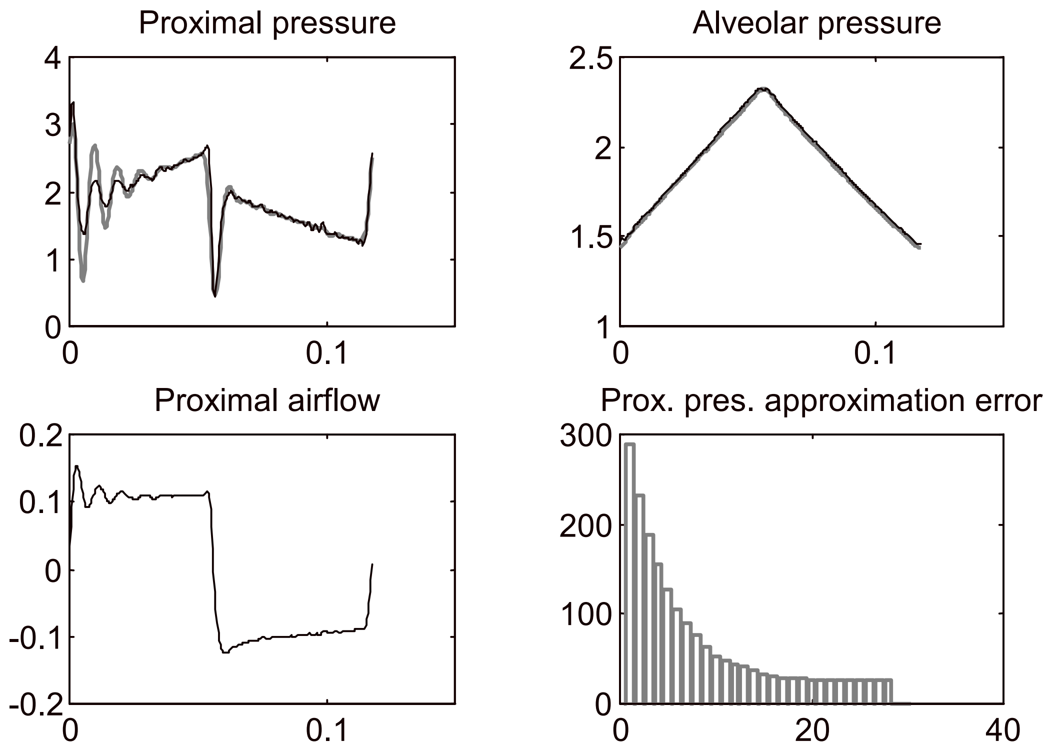


Fig. 10: Final stage of the iteration. Explanation in text.

identified model. The first iteration of the whole process is presented in Fig. 9, while the final stage in Fig. 10, where the similarities of the measured and computed courses of both proximal and both alveolar pressures are evident.

The other exercises solved during computer labs seminars from the subject "Biological signals" are:

- Filtration of EEG signal – extraction of basic rhythms
- Compression of ECG signal – compression based on Walsh-Hadamard transform with reduction in spectrum and reduction in bit depth.
- Adaptive filtration of ECG – adaptive filtration of 50 Hz interference in ECG signal (2 approaches)
- Filtration of ECG signal – ORS spectrum, baseline fluctuation elimination
- QRS-complex detection in ECG signal
- Noise elimination using averaging technique – averaging technique applied on evoked potentials and ECG signal
- Cepstral analysis – principles and application on biosignals

Conclusion:

Computer aid education of biosignals using MATLAB system preserves the possibilities of direct work with biosignal data and development of processing algorithms while other programming and visualisation techniques can be simply realised.

This structure and the form of education during computer lab seminars lead to the fact that students are familiar with the basic biosignals, they know well their properties and algorithms of their processing.

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