Educational Software for a Student Laboratory of Automated Electrocardiogram Analysis

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ABSTRACT

The paper presents software for baseline formation in acquisition and automated interpretation of electrocardiograms for students of the "Electronic Equipment" specialization, AGH. Special pressure has been put upon the educational values of the presented software, as it has ben designed as laboratory equipment. Despite, the implemented software solutions are representative for the development of automated ECG analysis worldwide in the last ten years and they have been implemented in the currently manufactured equipment as well as in the sets of worldwide standard test signals (ECG-databases) with descriptions.

1. PROFILE OF THE EDUCATION

The Laboratory of Biocybernetics, AGH has been forming students of Electronics in principles of electronic medical equipment construction for several years. The systematic introduction of microprocessor technology to the modern medical equipment made the authors broaden the program with the issues of automated processing of different biomedical signals (ECG, EMG, ENG, EEG). Of course, because of its demonstrative character and availability the signal representing the heart electrical activity has been given the priority.

The program of the acquisition and automated analysis of ECG signal includes the following issues:

- electrophysiology of the cardiac muscle (myocardium)
- influence of the electrode-skin contact on the ECG signal quality
- systems of the ECG leads and influence of the electrode disposition on the ECG curve shape
- construction of signal circuits of the recorders and A/D converters
- ECG signal filtration in terms of frequency and time-frequency domain
- methods for compression and expansion of ECG signal
- stages of ECG signal processing for determination of diagnostic parameters
- software detectors of the QRS complex in the electrocardiogram rule of the optimum spatial superposition of the vectorcardiographic loops
- analysis of series of diagnostic parameters
- methods for qualitative evaluation of the software supporting ECG diagnostics [5].

The aim of such an extensive program of student laboratory practicals concerning ECG processing is to train an engineer in electronics who has an overview of the current knowledge of the subject in the electronic medical equipment field, despite the increased role of the software. Of course the issues approached in the electrocardiography subject remains actual also in other fields of medical elecrodiagnostics. Graduates often becoming chairman or designers in electronic medical equipment firms are evidence for the success of the implemented teaching program.

2. SOFTWARE FOR LABORATORY PRACTICALS

To allow implementation of the described program, the laboratory is equipped with the following:

- electrocardiograph Ascard-3 [6], allowing polycardiographic recording and automated analysis and calculation of the ECG diagnostic parameters. Thanks to the good will of the manufacturer, the equipment software allows access to unprocessed signals for educational purposes.
- operating models of single-channel signal circuits of the electrocardiograph (2 sets), being manufactured by the Laboratory of Biocybernetics, AGH.
- universal A/D, D/A converter board, PCL 818 [7] type with amplifiers allowing recording of biological signals, with the appropriate software
- two universal biopotential recorders, built on design of the Laboratory of Biocybernetics, AGH personnel.

The software for laboratory practicals can be divided into three groups:

2.1 Educational and demonstration software obtained from interested cooperating firms

- CAVIAR [1] being a demonstration of the automated optimum spatial superposition of the vectorcardiographic loops
- DIGISCOPE [3] being a student set of exercises in processing the ECG signal at WISCONSIN-MADISON UNIVERSITY. It cooperates with the MIT-BIH [2] database and (after a slight transformation) with the PCL 818, that allows students to introduce their own electrocardiograms.

2.2 Educational software developed by the staff of the Laboratory of Biocybernetics, AGH (or under their supervision) as so called computer lessons. The common feature is a closed structure, as they have been written to present a particular issue (mainly in C programming language). This group includes:

- an introduction to the electrophysiology of the myocardium and presentation of the electrocardiographic leads (cooperates with the MIT-BIH database)
- simulation of the ECG curves from randomly selected points on the patient's body, based on vectorcardiographic signals (cooperates with the CSE database [4])
- presentation of the QRS complex detector operation on the filtered signal (cut-off frequency 35 and 50 Hz) and unfiltered (cooperates with the Ascard-3 electrocardiograph and allows operations on curves introduced by the students) QRS complexes classification using a neurone network (cooperates with the MIT-BIH and CSE databases)
- demonstration of features of the basic ECG signal compression and expansion methods ("turning point", AZTEC, "fan", Huffman's coding, single step estimate) the degree of compression and signal distortion is calculated (cooperates with any disc files)

- comparison in the spatial vectorcardiographic loops allowing the so called manual optimum superposition with geometric transformations of one of the compared loops (cooperates with the CSE database)

2.3 Educational software developed by the Laboratory od Biocybernetics, AGH personnel (or under their supervision), as so called computer experiments. They have an open structure, that means allow students to add their proposals of solutions for problems being part of the software support for ECG diagnostics. The system environment for this group of applications is the Matlab 3.5 [8] - environment for numerical experiments (despite the fact that some of its parts are operating software units). This group includes:

- presentation of the electrocardiogram processing leading to diagnostic parameters - allows introduction of own QRS complexes detection algorithms, QRS complexes classification, etc., and also testing the particular stages and the whole processing adding noise interferences or isoelectric line variations to the signal at a given ratio (cooperates with the MIT-BIH database),
- presentation of the features of five basic QRS complex detectors operating in real-time or off-line on one or several ECG leads - allows designing of an own QRS complexes detector and comparing its properties with the presented devices (cooperates with the MIT-BIH database)
- model evaluation of software supporting ECG diagnostics, allowing introduction and evaluation of own software solutions in the range of: QRS complex detectors, QRS complexes classification and calculation of diagnostic parameters [5] (cooperates with CSE database)
- comparison in the spatial vectorcardiographic loops, allowing addition of own QRS complex detector and investigation of its importance for adequate comparison of two loops (cooperates with the CSE database)
- testing the adaptative ECG signal filtration in the time-frequency domain, allowing any formulation of rules for the adaptative selection of filtration characteristics and comparison of the filtered signal with the primary course (cooperates with any disc files)

3. CONCLUSIONS

Presentation of the issues related with automated analysis of electrocardiograms (or more generally: use of mathematical methods for biological signal processing) requires development of a specialized educational background such as demonstration, educational and experimental software and its continuous updating. Such applications should be adequately prepared parts of the commercial software, broadened with educational values. This would allow students to fully understand the rules of signal processing used in clinical practice. Additional enrichment of the educational software by experimentation capabilities (such as replacing some of its blocks) and even the simplest tools allowing evaluation of the quality of obtained results (such as standard ECG databases) will uncover the creative predispositions of the trainees. Despite the fact that such a thesis seems to meet the expectations of the industry towards a technical university, it has not yet been confirmed by any of the potentially interested manufacturers.

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