Using Commercial Interpretive Software as a Teacher's Reference Tool in Digital ECG Laboratory

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Abstract

This paper presents the usage of purposely adapted ECG interpretation software as a classroom tool providing reliable reference values of most diagnostic parameters for ECG records from any source. The software maintains the commercial reliability and no part of its source code is disclosed. Additional checkpoints and data switches between the internal procedures (e.g. beat detection, classification, typification etc.) allow for tracking the intermediate results or for using own input data with selected range of processing procedures. The data sources are thus not limited to the databases, but include also custom-recorded and modified signals. Students, usually making their projects concerning a specific task of ECG interpretation, have a reliable reference values and may quantitatively compare their achievments. The software is very helpful to the assistant-professor with only basic background from cardiology for supervising the students' project. Our approach may also be beneficial to the manufacturer, since the statistics show that outcomes of some best students are increasingly competitive.

1. Introduction

Education of numerical methods and algorithms specific for automatic interpretation of biosignals belongs to principles of biomedical engineering or applied computer sciences curricula [1, 2]. Besides its practical importance, this topic has serious advantages with regard to teaching aims including the pursuit for innovations and thorough procedure-based verification, both being essential in bioengineers practice. If correctly managed, the laboratory or projects in biosignal processing may become a students' favorite, despite of intrinsic complexity and required mathematical background.

The electrocardiogram is particularly useful in student's laboratory of biosignal processing. Students get used to non-invasively recording this clearly structured signal from themselves using inexpensive devices and awareness of the role of cardiovascular system, raises their involvement and understanding of physiological backgrounds and necessary human- or computerized interpretation principles. In our laboratory teachers are rather engineers than cardiologists and therefore they need a reliable tool providing accurate interpretation results as reference for students' projects.

Two kind of reference are available to both teachers and students working with ECG interpretation methods: databases and commercial software. Although reliable and widely recognized, databases are closed sets of examples and provide only selected diagnostic parameters as the output. Commercial software packages accept input from any source (however may require a format conversion), but due to a closed architecture provide only final values resulting from a complex processing chain. The use of Open Source software, although allows for unlimited code modification and parameter tracking, raises the question of reliability. Moreover, providing a source code also to students weaken their ambition for own innovation and draws their attention to purely technical problems (compilation, execution efficiency), rather than to the interpretation methodology.

This paper presents the modification of a commercial software based on agreement made with the manufacturer with a goal to provide a reliable reference outcome for most ECG interpretation procedures with possible use of signals of any origin The solution presented beneath was put into practice since three years and revealed its advantages for organization of simultaneous development works of student teams and with unbiased quantitative validation of students outcomes based on both: custom- and database-originating ECGs.

2. ECG interpretation projects

2.1. Purpose of students' projects

Students' projects on ECG interpretation methods have 20 years of history at AGH University of Science and Technology in Krakow. Currently they are part of the lecture named "Biosignal processing" for the 1st semester students of the 2nd degree (Master) of "Applied computer science" faculty and of the lecture named "Dedicated algorithm for medical diagnostics" for the 1st semester

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students of the 2nd degree (Master) of "Biomedical engineering" faculty. Both lectures are accompanied by 30 class hours of laboratory exercises considering selected methods of biosignal processing and a semester project. Lectures are given by the Author while laboratory exercises and projects are supervised by two assistant-professors.

In general, projects are instrumental in technology-oriented education to foster various skills necessary for an independent professional and a candidate looked after by most attractive employers:

- literature research and experiment planning,
- decision making and critical result-based review of own proposals,
- team working, interpersonal communication and time organization.

As carrying out their projects students are particularly encouraged to show their own initiatives, supervisors are committed to hear, consider and evaluate any students' input, especially suggestions concerning the actions planned in context of external conditions and personal abilities. In a series of individual consultations or through electronic exchange of information, students are individually guided and systematically assessed by their supervisors in course of the semester. Having received a final report, the supervisor evaluates not only the technical correctness of the completed project, but also the innovative approach and proper justification of each decision step which is of particular concern as essential engineering skill.

2.2. Projects organization and schedule

As projects are intended for team working, students are asked to split into project teams of 2 – 3 persons. Each team applies for assignment of a complex task from the announced topic list. In the application they specify their interest, skills, expected outcome and realization schedule. For each individual topic the project team is expected to provide an intermediate report, a final report and a functional proof. Project-based courses end by a presentation seminar (usualy two sessions, 15 minutes per presentation), where each team reports its outcome in a visual form and answers questions from the audience. The estimated workload is 60 hours per person (four months, i.e. 15 weeks, tab. 1).

Table 1. Semester schedule of project execution.

Action	Time
application for task assignment	2nd week
intermediate report due	7th week
final report due	12th week
functional proof	13th week
presentation seminar	14th – 15th weeks

Another aim of the semester project is to present an idea of future employment, therefore students are working in simulated software manufacturing conditions:

- all use an imposed software development environment (Ms Visual Studio) and programming language (C++),
- all use common data structures for communication between procedures and with I/O data streams,
- all apply the same report form including bibliography research, procedure description, testing conditions and results.

Each team is expected to study, develop, implement and test a particular piece of ECG interpretative software of a hypothetical processing chain [3, 4]. Supervisors provide students with disk files separate for input signals and each of corresponding intermediate result issued from modified reference software, definitions of common data structures and service software for communication with them (fig. 1). Students may use any personal or published source of knowledge as a background for their own methods. Particularly often they benefit from the open Physionet database [5] or Computing in Cardiology meeting papers [6]. Each individual project is concluded by a written report, a public conference-like presentation and finally several teams compile their code together to yield a complete independent application.

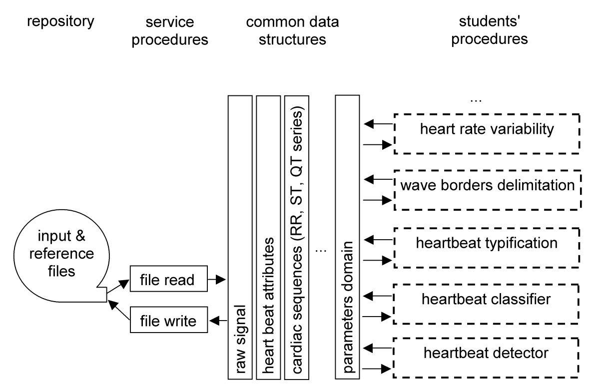

Figure 1. Block diagram of tools provided to and procedures expected from students carying out the project.

2.3. Attraction of ECG-based projects

Focusing all project task on ECG interpretation procedures gains wide acceptance and leads to personal involvment from students. Since the ECG may be captured relatively easy, it gives an unbeatable opportunity to develop self-awareness of the cardiovascular system and its function in presence of external factors (posture, load, temperature etc.). Students seeing themself as potential subjects of computerized electrocardiography understand the need for technological excelence and try to achieve best results in their projects.

As far as serious diseases are not concerned, students may record the signal from themselves and verify their methods in practice (e.g. immunity to electrode misplacement, muscular noise or motion artifacts).

Additional benefit comes from industry-like rules of projects:

- application for a topic requires a review of existing methods and critical assessment of own skills, experience, strenghts and weaknesses,
- working for a common goal motivates to strict adherence to data exchange rules,
- quantitative evaluation of results includes a spirit of competition between teams working on the same topic.

3. Modified software as a valuable support for teacher

3.1. Modification range

Originally, the commercial software (HolCard24W by Aspel [7]) was designed to provide long term analysis of 12–leads and 3–leads Holter records (12 bits, 125, 250 and 500 sps) and features full range interpretation of a selected signal strip. We assumed that it consists of functional blocks corresponding to the procedures developed as project tasks [8-10]. Based on an agreement of the University with the Manufacturer, we designed the requested structures of intermediate ECG interpretation parameters (e.g. description of a heartbeat) with corresponding file services and asked the manufacturer to include our code to a purposely compiled executables. Two versions of the "educational" software were built:

- earlier, where structures of intermediate variables were available only for reading to preserve the original reliability of the interpretive software, and
- later, implementing data switches which allow for substitution of the orginal values of intermediate variables by artificially prepared or modified data.

In neither case the ECG processing was modified in any way and remains undisclosed to us. The manufacturer guarantees that the software complies with current requirements on the accuracy of ECG measurements and correctness of diagnostic outcome. Therefore we can use the readouts of intermediate and final parameters as reference for evaluation of students' projects concerning the respective ECG processing range. Nevertheless, providing unusual values as intermediate variables input may violate the range in which the software was tested and result in its abnormal behavior.

3.2. Using modified software as data source

The modified software is used as a source of intermediate data for any ECG signal used for projects development. The 2–leads 360 sps records from Physionet (e.g. MIT–BIH Arrhythmia Database [11]) are converted to 500 Hz with one signal repeated to the 3rd channel. Other sources of data: CSE Multilead Database [12] and custom recorded electrocardiograms (with Ascard A4 or Aspect 812 by Aspel) were used in projects without conversion. It was interesting to independently confirm the compliance of the software with the requirements of the standard IEC 60601-2-51 [13] concerning the detection accuracy (with use of MIT–BIH Arrhythmia Database) and the waves delineation (with use of the CSE Multilead Database).

Depending on the topic, in some projects the raw ECG was used as input (tab. 2), while the others use only intermediate data delivered by the modified software. The intermediate data (or final diagnostic outcome) for respective ECG records are also used as reference values for evaluation of methods developed by students. First they perform self-validation or cross-validation of the algorithm with the concurrent project team with use of an open set of records. Results of this first evaluation is also used for the presentation of the project in the seminar. A second independent validation is performed by the supervisor using a hidden set of ECG records. These results are revealed after the presentation and influence the final scores.

Table 2. Data sets used in projects.

Project topic	Input	Reference
heart beat detector	raw ECG	detection points
beat classifier	raw ECG detection points	cluster membership
beat type detector	raw ECG detection points cluster kernel	type attribute
wave delineator	raw ECG detection points type attribute	wave borders sections' length
arrhythmia detector	RR series type attribute	arrhythmia types & attrib.
ST segment analyzer	raw ECG RR series type attribute	ST segment parameters, ischemia class.
HRV analyzer	RR series type attribute	HRV parameters

Figure 2. presents the block diagram of use of the modified software as a source of input and reference data for example projects. Both the open and the hidden test

sets are processed in the same way. The use of standardized structures for intermediate data, provided service procedures (see fig. 1) and definitions of common structures was strictly required. Therefore any divergence between students' result and the reference is considered as quantitative measure of quality of applied procedure.

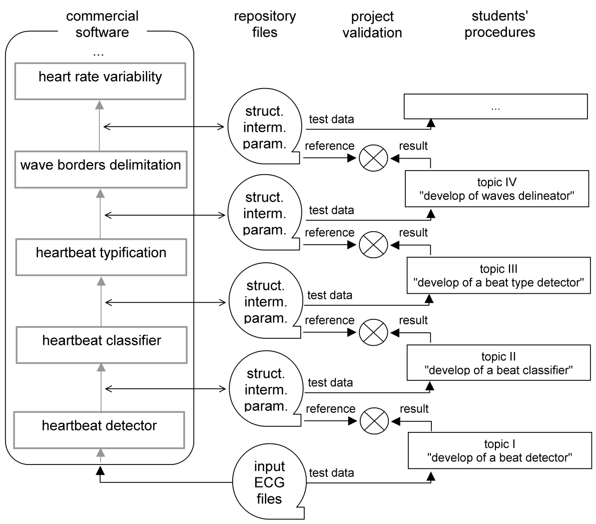

Figure 2. Block diagram of use of the modified software as a source of input and reference data for example projects.

4. Results

Main result of the presented educational approach and of using the modified commercial interpretive software as a teacher's reference tool in digital ECG laboratory are quality of students' projects and achievment of the educational aims. Students' solutions are validated in an unrelated, transparent and repeatable manner and the interpretive software doesn't require a profound cardiology-oriented knowledge from the assistant-professor supervising the projects. Following the academic rules, students are educated independently, without reference, or examples to follow from any particular manufacturer.

Some projects show results very close to those of the commercial software. Consequently, the cooperating manufacturer expresses his interest in supporting of selected projects with a perspective of further interim cooperation or future employment.

It is noteworthy that for semester projects on ECG processing only the earlier modified software version is used, where structures of intermediate variables were available uniquely for reading. The other version, allowing for substitution of the orginal values of intermediate variables, is used in scientific research or selected diploma project as a validation service. Following this need, future agreement with the manufacturer is in course of negotiation aiming at preparing the interpretive software to run in a multithreaded server as a remote service.

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