ELECTROCARDIOGRAM RHYTHM SIMULATION IN OPEN SOURCE ENVIRONMENT

A Contribution to Training in Biomedical Sciences

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Abstract: Considering the importance of training and the need to identify some important electrocardiographic patterns, our aim was to develop a software-based electrocardiogram rhythm simulator, able to generate signals for purposes of training health care professionals, freely available. Additionally we intended to implement a training assessment and the ability to configure specific rhythms/patterns with user-defined settings.

In order to achieve the availability requirement we decided to develop our tool as open source. All the software was developed in Linux platform, but releases are available in binary format for Linux and Microsoft Windows platform.

The result was a functional signal simulator which satisfied all the requirements we proposed in our aim. The final result of our work is presented and available at Sourceforge.

1 INTRODUCTION

Electrocardiographic signal is a graphic representation of the electrical activation (depolarization) and repolarization of cardiac cells, as a result of the expression of main activation vector in each lead. In an electrocardiogram (ECG) strip it is possible to identify several incidents, that concern specific electrical activity. Additionally it is possible to define a number of intervals and segments between these main incidents, that concern stimuli conduction and that do have clinical correspondence, with a determined “normal” duration, amplitude and morphology (Lipman and Cascio, 2001; Wagner, 2006).

Presently, and more than 100 years passed over its introduction in clinical practice by Willem Einthoven (Moukabary , 2007), the ECG is still a valuable diagnostic instrument. The astonishing technological evolution felt in the medical field in the past 50 years, with particular relevance in Cardiology, created the misconception that newer techniques have replaced electrocardiography. Not only is the electrocardiogram an important diagnostic tool, but also to guide the treatment of common severe cardiac conditions, and determine patients prognosis(Hurst, 2003).

Training of biomedical professionals is crucial for patient care. The ability to train procedures, establish diagnosis and define prognosis of a disease prior to applying that knowledge in real-life patients is an enormous advantage for both professionals and patients, with clinical, legal, and ethical implications. In terms of ECG, the wide variety of normal patterns, sometimes quite different from each other, and the difficulty to identify some subtle abnormal patterns makes prior training not only necessary but also imperative. The acknowledgement of training needs, lead to the development of a joint guideline for training in electrocardiography (Kadish et al., 2001).

A wide variety of ECG simulators, electronic or software-based, both commercial and non-commercial, are currently available. A series of commercial devices, using just an electronic approach, were built especially for ECG rhythm simulation and training. Nowadays they are currently in use, but only for specific training and maintenance of medical equipment. With the explosion of computer technology back in the 1970's and 1980's several computer programs[6,7] were developed for ECG and pacing rhythm training and

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simulation. Those systems seem to have been abandoned (at least for what concerns free software implementations), with a few exceptions, probably due to severe limitations namely in scientific contents. Conversely, a series of well developed ECG rhythm simulation programs is currently available for commercial use. Additionally, an unaccounted number of advanced life support (ALS) manikins are also available, allowing the chance to diagnosis and treat malignant arrhythmias (Mueller et al., 2005; Schlindwein et al., 2002; Gordon, 1974). However these training manikins are somewhat limited in their ability to deliver and simulate certain electrocardiographic patterns as they are more emergency training oriented.

As far as we know, there is presently no ECG simulation tool widely available to everyone, able to receive suggestions and improvements from a wide variety of professionals of medical and other scientific areas, that can be freely improved and reviewed by experts. As stated before, some exceptions (Karthik, 2002) are available, but with limitations, like the requirement of a third party software license (Matlab) or lacking usability for everyday usage.

Considering the importance of training and the need to identify some important electrocardiographic patterns, our aim was to develop a software-based ECG rhythm simulator, able to generate ECG signals to train health care professionals, freely available. Additionally we intended to implement a training assessment and the ability to configure specific rhythms and patterns with customizable settings. In order to achieve the availability requirement we decided to develop our tool as open source, therefore we have chosen the GNU Public License (GNU General Public License, 2009) GPL v3 license model.

2 METHODS

We performed a search in the Pubmed (PubMed, 2009) reference database regardless of the type of publication. For addressing the database, we used the query: “electrocardiogram [MeSH] AND training [MeSH] AND simulator” with limits selected for “English language” and “Humans”. The query was performed on the 15th May 2009 and returned 6 articles for analysis. The analysis was performed by all investigators. Selection criteria were defined prior to the query and included: 1) type of study; 2) critical analysis of the results, and 3) suitability to our subject. After applying the above criteria, we selected two articles (Fukushima e tal., 1984; Gordon, 1974). This method, despite its scientific reliability, does not take into account the existence of other not so formal initiatives. To understand the state of development of commercial and non-commercial ECG simulation tools we performed a qualitative survey using the same terms on Google search engine. The result, with the limitations of being a qualitative survey, made clear that a wide variety of tools is available but not with the type of development we tried to implement.

2.1 Implementation

As the first task of the project, we tried to find a simple and flexible way to generate signals that could be similar to those of human ECG with different patterns. Fourier series were selected for representing ECG signals, as any periodic functions which satisfy Dirichlet's condition can be expressed as a series of scaled magnitudes of sin and cos terms of frequencies which occur as a multiple of fundamental frequency. ECG signal is periodic with fundamental frequency determined by the heat beat (Karthik, 2002). Each significant feature of ECG signal can be represented by shifted and scaled versions of waveforms.

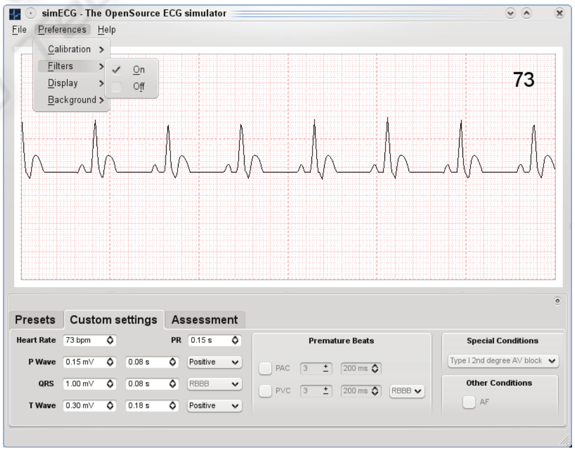

Figure 1: simECG version 1.0 screenshot showing custom settings.

2.2 Environment

The Qt 4 development framework was chosen to implement the project, as it is very flexible, uses C++ as the programming language with easy-to-use graphical user interface support, and is available in many different operating system platforms. Another

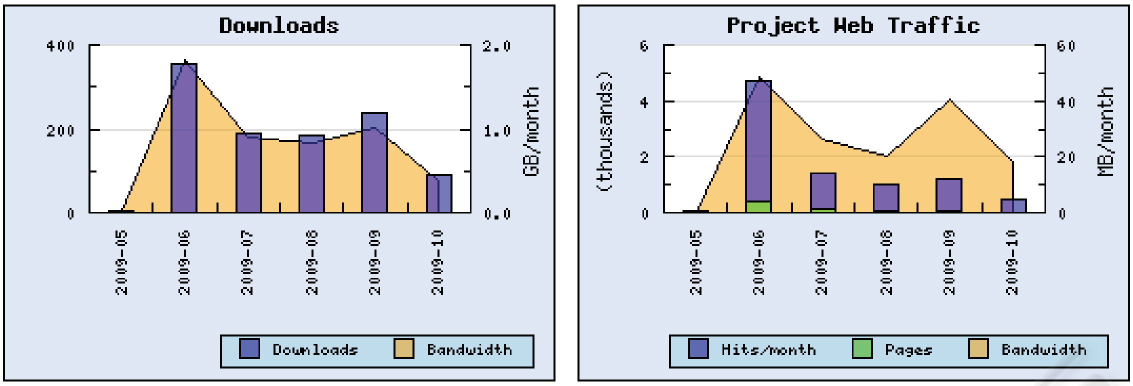

Figure 2: simECG activity (downloads and traffic) on Sourceforge.

reason, was that Qt (Qt4 cross-platform application and user interface framework, 2009) version 4 has a licensing model that allows the use of GPL to develop an open source software solution. The software was developed using many tools, however the most important ones were Qt Creator (Qt Creator Integrated Development Environment, 2009) as the integrated development environment (IDE), and Sourceforge (Sourceforge, 2009) as the project management system that provided a complete software build platform, that includes .svn for source code repository, package release file system repository, mailing lists and forum for developer discussion, bug and feature tracking system, and a project web page. All these resources are publicly available (simECG sourceforge project page,).

2.3 Programming

The architecture of the project lead to C++ classes that implemented the intended block behavior. “Signal Plotter” displays an ECG signal in a typical ECG strip format, which was in turn created by “ECG generator”, that calculates the signal based on the above described Fourier series, adjusted by the user settings. In turn, every setting, preset or custom, is stored as an “ECG Presets” class. Every time the user runs an assessment, its corresponding class is instantiated. The assessment controls a set of 10 questions which the user should select the correct one displayed. Three presets are randomly chosen, but only one is accordingly displayed. The myMainWindow class, implements the main program window, menu toolbar, docking toolbar with a tab separator, and all the graphical widgets present. It is the class that glues all the code, mainly through the concept of signals and slots, that is very well known in Qt development.

2.4 Dissemination

The simECG application was disseminated via the Sourceforge, with the first beta released on the 29th of May 2009. The simECG project included bugs, features, and users/developers forum was created to help disseminating the application. In the next section we report the tracker activity since the first release.

3 RESULTS

3.1 Application Features

simECG has several features, that allows the user to display predefined ECG signals such as: sinus rhythm, bradycardia or tachycardia; junctional rhythm; accelerated junctional rhythm; idioventricular rhythm; accelerated idioventricular rhythm; supraventricular tachycardia; monomorphic ventricular tachycardia (VT); ventricular fibrillation; first degree atrio-ventricular (AV) block; and AV dissociation. Additionally the user can also define some custom settings, such as heart rate; PR interval; P, QRS and T waves duration, amplitude and polarity. Nevertheless, some bugs still persist and are being corrected specially through the Sourceforge community infrastructure.
The activity in the project, despite being considered a recent release, seems to reflect the good adherence from the community.

4 DISCUSSION AND CONCLUSIONS

The simECG is able, as stated in our aim, to generate ECG signals, for purposes of training health care professionals as an open source solution, freely available to the community from now on.

The final result of our work is presented and available at Sourceforge (Sourceforge, 2009) in the simECG project page (simECG sourceforge project page,) as version 1.0. All the software was developed in Linux platform, but releases are available in binary format for Linux and Microsoft Windows platform.

With the release of simECG 1.0 the first steps towards the building of a community were taken, based on the premises that: all the components of the project should be developed on Open Source applications; all the contribution should be "non-paid"; all the releases should be free; and the source code should be available for everybody to read, interpret and re-write. All those premises along with the idea that the authors alone could not support such a project, lead to the creation and maintenance of simECG at Sourceforge.

With just a few months online, the authors think the project as a good chance of succeed. The download and traffic rates are quite reasonable. Feedback from users and participants has been good, although until now we could only recruit one new contributor. Nevertheless the project will audited at six months in order to compare the web traffic with other projects, namely in healthcare related projects, and potential contributors. This is allow the authors to identify more accurately the directions the project should take.

4.1 Limitations and Future Perspectives

At the moment simECG cannot be integrated in other solutions, as it was designed to be a standalone interface and does not provide "standards-based" interface.

Authors also recognize that more experimental results are needed, and a comparative evaluation should be performed.

Future work includes implementation of some features and custom settings, such as premature atrial or ventricular contractions, atrial fibrillation and some special conditions (second degree AV blocks and polymorphic VT) that were implemented in this version due to time constraints. For that same reason, was not possible to implement the atrial fibrillation pattern. The implementation of ECG motion (rolling) needs further advanced research. In future versions the authors intend to provide additional features in the training presets and include additional settings.

All pending bugs and requested features are described in detail in the Sourceforge tracker service, and need to be object of close attention in future versions.

simECG will always be an unfinished project. In the future authors intend to build and support a community, with the intention of releasing new improved versions.

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