

Development and Testing of Ventricular Fibrillation Detection Software Module

Alexander Borodin, Artem Pogorelov, Yuliya Zavyalova
 Petrozavodsk State University (PetrSU)
 Petrozavodsk, Russia
 {aborod, pogorelo, yzavyalo}@cs.petsu.ru

Abstract—The most dangerous type of cardiac abnormalities - ventricular fibrillation. It is necessary to develop an algorithm for real-time ventricular fibrillation detection for mobile application CardiaCare, to be able to make an emergency call in a timely manner.

I. INTRODUCTION

Sudden cardiac arrest is a major health problem, because cardiac arrest - one of the leading causes of mortality both in developed countries. In most cases, the process starts ventricular tachycardia (increased heart rate) which rapidly progresses to ventricular fibrillation. Ventricular fibrillation is characterized by a reduction in myocardial fibers chaotically with frequency 250-480 per minute, absence of coordinated ventricular substantially, heart failure with shutdown of vital bodily functions. Ventricular fibrillation always comes suddenly and it is imperative to defibrillate using special equipment as soon as possible.

As the detection of ventricular fibrillations produced in real time at the mobile device, to the algorithm in addition to reliability, is required high speed and computational simplicity.

II. TIME-DELAY ALGORITHM

The time-delay algorithm (PSR — phase space reconstruction) is based on a method which is used to reconstruct the so-called phase space. It analyzes signals in order to identify a dynamic law or random behavior. [1] The signal $x(t)$ is plotted in a diagram in the following way: on the x-axis we plot $x(t)$, on the y-axis $x(t+\tau)$, τ being a proper time constant. Such a plot is called a two dimensional phase space diagram.

Observed that a typical VF signal produces a curve in the diagram, that fills the area in an irregular way. The curve is almost uniformly distributed over the entire diagram. However, for a normal sinus rhythm the curve in the phase space diagram shows a regular structure, only small parts of the area are filled, and the curve is concentrated to a restricted region of the plot. In the special case of a periodic signal for example, where τ is a multiple of the period all points lie on a line of 45 degrees. Based on phase space plots $(x(t), x(t + \tau))$ we differentiate SR from VF. We determine the area of the plot filled by the curve. To achieve this, we produce a 40×40 grid and count the boxes visited by the ECG signal. The 40×40 grid stretches from the minimum to the maximum of the investigated raw ECG signal. We then calculate a measure d defined by

$$d = \frac{\text{number of visited boxes}}{\text{number of all boxes}}$$

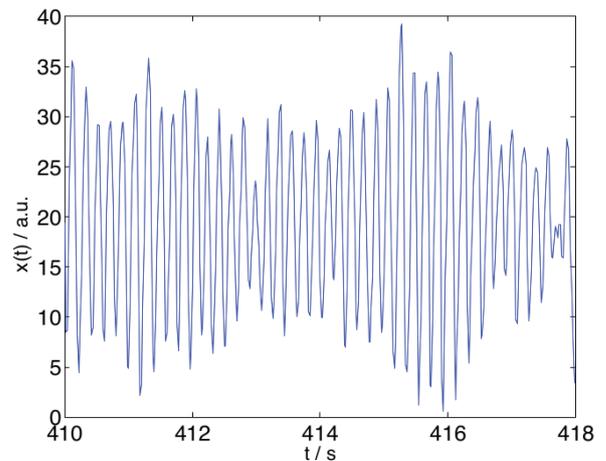


Fig. 1. VF episode in the ECG signal

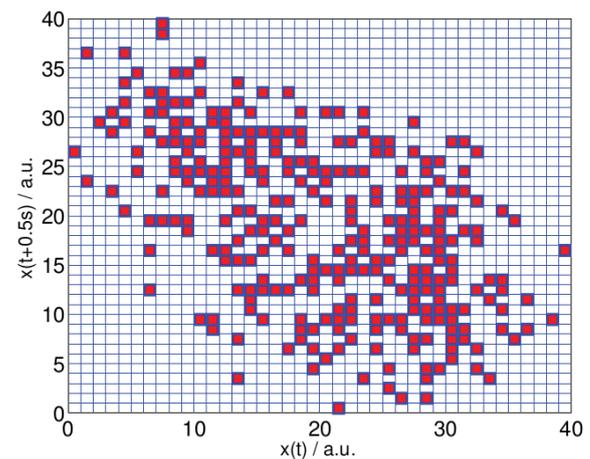


Fig. 2. Data points of a VF episode in the ECG signal; visited boxes visualized in a phase space diagram, $d = 295/1600 = 0.18$.

If d is higher than a certain threshold d_0 , we classify the corresponding ECG episode as VF. We chose $\tau = 0.5s$ and for the threshold $d_0 = 0.15$. The number of boxes is 1600.

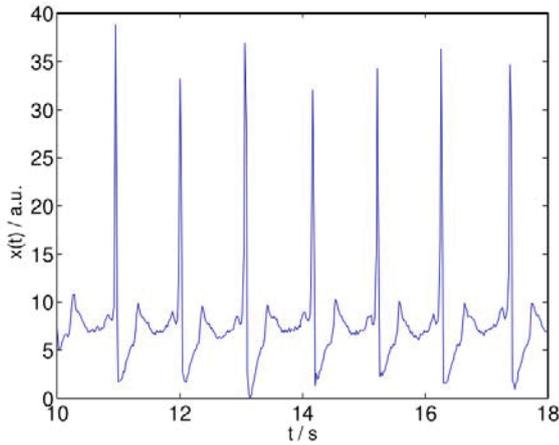


Fig. 3. SR episodes in the normal ECG signal

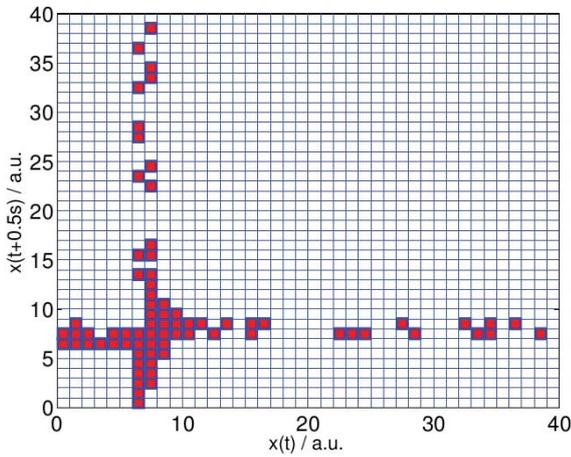


Fig. 4. Data points of SR episodes in the normal ECG signal; visited boxes visualized in a phase space diagram, $d = 74/1600 = 0.05$.

III. DEVELOPMENT OF VENTRICULAR FIBRILLATION DETECTION SOFTWARE MODULE

Appointment of a mobile application CardiaCare - to provide to physician-cardiologist ECG data and primary results of automated diagnostics. Upon detection of high-risk cardiac abnormalities, CardiaCare application can make an ambulance emergency call.

ECG data in a mobile application are handled in real-time. Heart monitor sends via Bluetooth wireless technology data packages at a specified frequency. Bluetooth-module of application on the smartphone receives these packages and passes control to module of data parsing that extracts the necessary information from the received package: a model of heart monitor, its parameters, the frequency of readout, units of measurement, the recorded values of ECG. It is in the form of the number sequence ECG data is transmitted to the analysis.

The first module of the mobile diagnostic application is analysis for the presence of ventricular fibrillation, as it is the most dangerous type of disorders of the heart, and it is require

early detection and emergency response.

The algorithm is indicated in the previous section and the implementation of module is described as follows:

- 1) The package of data is received. The size of received data is determined by the specification of heart monitor.
- 2) Package divided into a plurality of sections, each section 8 seconds long. The number of sample values in this section may be different.
- 3) For each section, constructed the corresponding two-dimensional:
 - a) Determined the maximum and minimum values at the section.
 - b) Calculated the correction factor for all values can be presented on the interval $[0..40]$.

$$k = \frac{\max - \min}{40}$$
 - c) All values of section are converted $x(t) = k \cdot x(t)$.
 - d) Created a two-dimensional plot (array) dimension of 40×40 and completely filled with zeros.
 - e) Values of two-dimensional plot (array) are changed in accordance with the rule: $y[x(t)][x(t + \tau)] = 1$. In the array y will stand the unit on the ground with only the indexes $x(t)$ (row number) and $x(t + \tau)$ (column number) that after the conversion in step 3.c) store values $[0..40]$.
- 4) For each two-dimensional plot (array) counted n = number of units in the array y .
- 5) Calculated the coefficient $d = \frac{n}{1600}$.
- 6) Criterion of the algorithm, $d < d_0$
- 7) If coefficient d is greater than the threshold value d_0 , then detected the section with ventricular fibrillation.
- 8) Data block which are marked on the presence / absence of ventricular fibrillation transmitted to the ECG storage module.

After performing the analysis, ECG data with notes on the detected arrhythmias in each section are recorded with the ECG storage module in .edf file[2].

IV. TESTING OF VENTRICULAR FIBRILLATION DETECTION SOFTWARE MODULE

Testing was performed using database records of cardiac arrhythmias MIT-BIH [3] in the PhysioNet (USA)[4]. PhysioNet is a resource for biomedical research and development sponsored by the National Institute of Biomedical Imaging and Bioengineering (NIBIB) and the National Institute of General Medical Sciences (NIGMS), two institutes of the National Institutes of Health (NIH).

PhysioNet provides free web access to the research community to a large collection of records physiologic signals and associated open-source software. The data available on this web-site includes records of various biomedical signals, both healthy people and patients with manifestation of a variety of pathologies and disorders.

In the testing of module was used software package WFDB (WaveForm DataBase)[5], which contains the WFDB-library (set of functions to work with databases PhysioBank) that available for programming language ANSI/ISO C, K&R C, C++ and Fortran, as well as a set of necessary WFDB-applications written using the WFDB-library.

Has been studied directory MIT-BIH, been selected a set of ECG recordings with various ventricular arrhythmias, set of parcels ECG without any disturbance and areas with other types of arrhythmias. In the catalog all entries are numbered, each has a detailed description. In particular, the information is available, what type of cardiac abnormalities and what time on each record is fixed.



Fig. 5. Normal ECG record, MIT-BIH Arrhythmia Database (mitdb); plot obtained by PSCHART application[7].



Fig. 6. ECG record with VF, MIT-BIH Arrhythmia Database (mitdb); plot obtained by PSCHART application[7].

Further, using the WFDB-application RDSAMP [6] selected records were obtained with the MIT server to a local drive and saved in text form. For obvious reasons it is impossible to carry out the testing of ventricular fibrillation detection in real-time, therefore was written a convenience application that performs the following functions:

- Providing an interface to select the directory where files with ECG recording stored.
- Parsing of the MIT-BIH database files.
- Bringing the ECG data to the same format and structure as in a mobile application CardiaCare.
- Connecting to the ventricular fibrillation detection algorithm as a source of data.
- Printing results of analysis.

Test application shows the performance of realized module. The algorithm correctly identified the presence / absence of the desired violation of the sites studied ECGs.

Examples of work of algorithm are presented in Fig. 7 and Fig. 8 — shown screenshots with the results of testing of the algorithm (red font) on the corresponding ECG recordings.

V. CONCLUSION

Submitted screenshots demonstrated the correct operation of the algorithm. The values of the coefficient d for several consecutive 8-second intervals less than $d_0 = 0.15$ for ECG recording of a healthy person, and above this threshold in the case of research ECG with ventricular fibrillation.

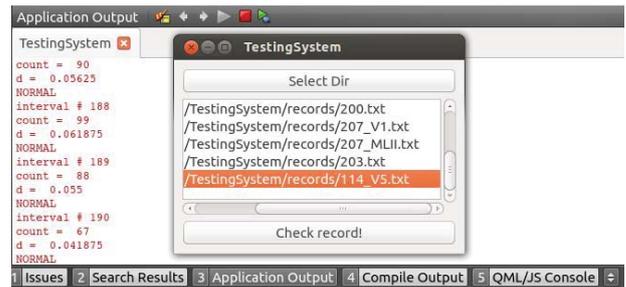


Fig. 7. Normal ECG record analysis, MIT-BIH Arrhythmia Database (mitdb)[3]; output of testing application with the results of ventricular fibrillation detection.

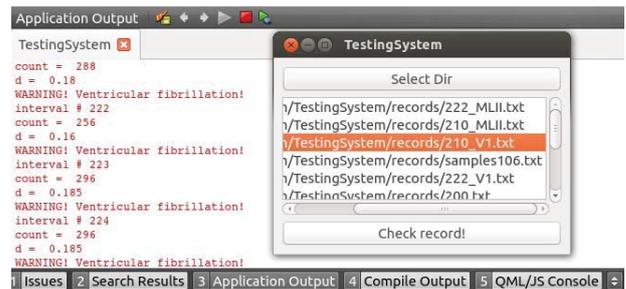


Fig. 8. ECG record with VF analysis, MIT-BIH Arrhythmia Database (mitdb)[3]; output of testing application with the results of ventricular fibrillation detection.

ACKNOWLEDGMENT

This research is a part of grant KA179 Complex development of regional cooperation in the field of open ICT innovations of Karelia ENPI programme, which is co-funded by the European Union, the Russian Federation and the Republic of Finland. The article was published with financial support from the Strategic Development Program of Petrozavodsk State University. We are grateful to the Open Innovations Association FRUCT for its support and R&D infrastructure. We would also like to thank Sergey I. Balandin and Iurii A. Bogoiavlenskii for their feedback and expertise.

REFERENCES

- [1] Anton Amann, Robert Tratnig, Karl Unterkofler "Detecting Ventricular Fibrillation by Time-Delay Methods", Research Center of Process and Product Engineering, FH- Vorarlberg, Austria, 2007.
- [2] European Data Format Specification (EDF), Web: <http://www.edfplus.info>
- [3] MIT-BIH Arrhythmia Database Directory Specification, Web: <http://physionet.org/physiobank/database/mitdb/>
- [4] PhysioNet — the Research Resource for Complex Physiologic Signals, Web: <http://www.physionet.org>
- [5] WFDB (WaveForm DataBase) Software Package, Web: <http://www.physionet.org/physiotools/wfdb.shtml>
- [6] RDSAMP — read WFDB signal files, Web: <http://www.physionet.org/physiotools/wag/rdsamp-1.htm>
- [7] PSCHART — produce annotated 'chart recordings' on a PostScript device, Web: <http://www.physionet.org/physiotools/wag/pschar-1.htm>