

Intelligent Data Processing Scheme for Mobile Heart Monitoring System

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Abstract—Paper describes some aspects of data processing in mobile heart monitoring systems. Authors highlight an important cardiological and social problem of arrhythmic pathologies of the heart and the possibilities of new medical equipment to detect the arrhythmia. The architecture and the features of up-to-date monitoring systems are investigated. The specificity of long term ECG records is examined via the example of PAF Prediction Challenge Database from physionet.org. The scheme of open architecture modular ECG device is developed for experimental research of HRV analysis and arrhythmia paroxysms prediction. Data processing scheme that enables to design portable monitoring system for the detection of signs of arrhythmia and predict the arrhythmia paroxysm is proposed. Set of required ECG signal processing methods and algorithms is chosen.

Keywords—ECG signal analysis; data processing; patient state estimation; cardiology; time series; prognosis

I. INTRODUCTION

Cardiovascular diseases is an important medical and social problem, because it is the first among the reasons of human death and physical disfunction. They can often proceed rapidly and result in a lethal end [1]. Nowadays most actual cardiovascular diseases are arterial hypertension, acute coronary syndrome, abnormalities of heart rhythm and conductivity.

Technical equipment of medical institutions allows to collect and accumulate large amount of diagnostic data that can be used for estimation of state and prognosis of clinical course on the basis of modern pattern recognition and time series prognosis methods.

II. THE CURRENT STATE OF THE PROBLEM

Solving this problem is the aim of mobile (portative, personal) cardio monitors. These devices [2], [3] are able to monitor ECG signals for a long period of time and detect some

signs of dangerous heart conditions before they can cause serious damage.

Some of these systems are able to wirelessly transmit ECG data to a computer or medical server for the following professional analysis by a cardiologist.

Common functions of the systems are heart rate monitoring, ECG recording and transmitting to the server. Main focus of the modern heart monitoring systems is given on heart-rate variability (HRV) analysis, but actual challenge is to predict a risk of arrhythmia during day-to-day activity.

Common architecture of mobile ECG monitoring system [4] consists of ECG recording device, mobile computing device, and remote server. Among common requirements to mobile heart monitoring system [5] most actual is automated detection of signs of arrhythmia (offline mode without connection to medical data server);

Free movement conditions are concerned with a number of difficulties and limitations. Some of them are “reduced number of ECG leads, high level of noise and artifacts and limited time of autonomous device operation” [6]. Specificity of ECG recording in a free movement condition should be investigated and taken into account while designing a new system.

III. TECHNICAL IMPLEMENTATION OF MOBILE MONITORING SYSTEM

System for ECG monitoring [5] is based on the common architecture and consists of a portative ECG recording device and portable computer (smartphone or tablet) as shown in Fig. 1.

ECG device is a main part of the system, it implements ECG sensing, amplifying, analog-digital converting, contact break detecting, wireless data transmitting and some functions of self-control.

Smartphone is used as a mobile computing platform. It operates under control of Android OS. Specially developed

application is running on the smartphone. It interacts with ECG device, collects, store, visualize and process the ECG data, transmits it to the remote server or another mobile device. Analysis is performed to detect deviations in heart activity while day-to-day activity and to prognose a dangerous condition.

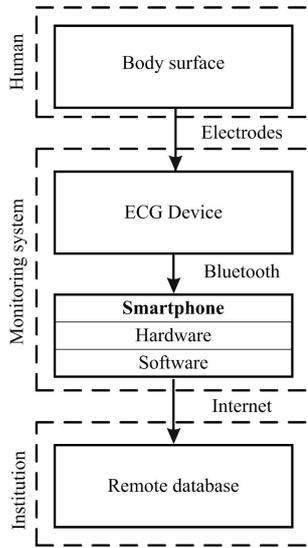


Fig. 1. ECG monitoring system

IV. THE SPECIFICITY OF CONTINUOUS ECG MONITORING

Analysis of ECG signals recorded during long term continuous monitoring has a number of specific features, concerned with the process of obtaining them.

Special long term ECG signals database is used for experimental investigations. This database consists of two-channel ECG [7], [8]. It is available for free at physionet.org. This base was specially created for developing automated methods for predicting paroxysmal atrial fibrillation (PAF).

ECG signal recording is accomplished during a normal day-to-day activity that includes episodes of physical activity of different intensity. These factors influence parameters of ECG electrodes contact with surface of the body and they can cause contact break.

Fig. 2 shows the moment of interruption in a large scale.

It can affect the following analysis such as HRV analysis and detection the arrhythmia. Periods of ECG signal interruption should be excluded from record before automated analysis.

Another problem arises when patient contacts with different electrical and radio equipment, that can generate radio noise and add this noise to recording ECG signal. This noise can be constantly present or episodically present.

Methods that are applied in stationary ECG equipment for filtering usually remove trend (low frequency filters 0.5-1 Hz), electrical network noise (rejection filter 50-60 Hz), muscular tremor (ant tremor filter 35 Hz). They are not able to remove noise and artifacts of other types. Therefore real-time analysis requires ECG signal filtering for reducing the

influence of different types of noise including noise from undefined sources.

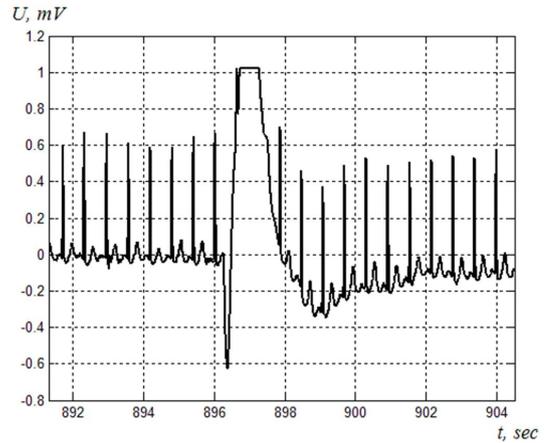


Fig. 2. ECG interruption example

V. DATA PROCESSING SCHEME

ECG data processing scheme for mobile heart monitoring systems should include preprocessing step and analysis step (Fig. 3).

Preprocessing step consists of the following operations: abnormalities detection for following excluding these areas from analysis process and filtering.

Abnormalities detection can be implemented with the help of special indicators, statistical parametrical or non-parametrical tests [9], [10].

Signals filtering can be implemented with the help of powerful methods based on the signal analysis like singular spectral analysis (SSA) or local approximation (LA) that allow to select specific features of ECG signal of concrete patient and use it for signal filtering.

Analysis step includes informative ECG parameters analysis [11], [12]. ECG signal parameters analysis can be implemented with the help of intelligent algorithms developed on the base of pattern recognition theory.

Algorithm of heart rate abnormalities prediction is based on the reconstruction of equations of distribution of heart rate frequency density with the help of quantile regression [13]. The algorithm consists of two main steps. The first step is learning, when ECG of the patient in “normal” condition is analyzed and coefficients of equations of density distribution of heart rate frequency are determined. It allows taking into account individual features of HRV of a concrete human. Then the algorithm predicts a distribution density of informative parameter for a few seconds ahead. After that running estimations of average of distribution and root-mean-square deviation of heart rate are calculated and their belonging to prediction density distribution is determined. High probability of belonging of current estimations to the prediction density distribution points to normal state. Episodes

of variance point to the possibility of arrhythmic abnormalities.

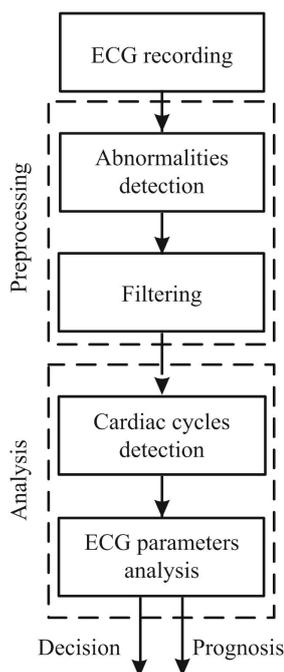


Fig. 3. ECG processing scheme

VI. CONCLUSION

The result of the research is a data processing scheme that takes into account specificity of mobile monitoring and allows to increase the effectiveness of signal analysis. It enables to design portative monitoring system for detection of the signs of arrhythmia and predict the arrhythmia paroxysm.

REFERENCES

- [1] Albert C., Mittleman M., Chae C. Triggering of Sudden Death from Cardiac Causes by Vigorous Exertion. *New England Journal of Medicine*, 343, 2000, pp. 1355–1361.
- [2] Kakria P., Tripathi N., Kitipawang P. A Real-Time Health Monitoring System for Remote Cardiac Patients Using Smartphone and Wearable Sensors. *International Journal of Telemedicine and Applications*, 2015, pp. 1–11.
- [3] Kumar S., Vashist E., Schneider M., Luong J. Commercial Smartphone-Based Devices and Smart Applications for Personalized Healthcare Monitoring and Management. *Diagnostics*, 4, 2014, pp. 104–128.
- [4] Borodin A., Zavyalova Y., Zaharov A., Yamushev I. Architectural Approach to the Multisource Health Monitoring Application Design. 17th Conference of Open Innovations Association FRUCT, Helsinki, Finland: FRUCT Oy, 2015, pp. 16–21.
- [5] Kuzmin A., Safronov M., Bodin O., Petrovsky M., Sergeenkov A. Device and Software for Mobile Heart Monitoring. Proceedings of the 19th Conference of Open Innovations Association FRUCT, Helsinki, Finland: FRUCT Oy, 2016, pp. 121–127.
- [6] Kuzmin A., Safronov M., Bodin O., Petrovsky M., Sergeenkov A. Mobile Heart Monitoring System Prototype Based on the Texas Instruments Hardware: Energy Efficiency and J-point Detection. *International Journal of Embedded and Real-Time Communication Systems*, Volume 7, Issue 1, 2016, pp 64–84.
- [7] Moody G., Goldberger A., McClennen S., Swiryn S. Predicting the Onset of Paroxysmal Atrial Fibrillation. *The Computers in Cardiology Challenge*. *Computers in Cardiology*, 28, 2001, pp. 113–116.
- [8] Goldberger A., Amaral L., Glass L., Hausdorff J., Ivanov P., Mark R., Mietus J., Moody G., Peng C.-K., Stanley H. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation*, 101(23), 2000, p. 215–220.
- [9] Bao Y., Lee T., Saltoglu B. "Comparing Density Forecast Models", *Journal of Forecasting*, 26 (3), 2006, pp. 203–225.
- [10] Kifer D., Ben-David S., Gehrke J. "Detecting Change in Data Streams", Proceedings of the International Conference on Very Large Data Bases, Toronto, Canada, 2004, pp. 180–191.
- [11] Clifford G., Azuaje F., McSharry P. (Eds.) *Advanced Methods and Tools for ECG Data Analysis*. Norwood, MA: Artech House, 2006.
- [12] Balakhonova S.A., Bodin O.N., Ivanchukov A.G., Polosin, A.G. Ubiennykh V.G. Increasing the reliability of heart condition estimation in computer diagnostic system "KardioVid". *Bulletin of Higher Education Institutions. Volga region. Engineering sciences*, 2 (38), 2016, pp. 61–71. (in Russian).
- [13] Mitrohin M.A., Zaharov S.M. Nonparametric density prediction for adaptation decision rule in the bayesian approach to the pattern recognition. *Radioengineering*, 2, 2016, pp.13–16.