Overview of Algorithms for Electrocardiograms Analysis

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Abstract

Long-term monitoring of heart function can prevent the number of the sudden deaths caused by heart diseases. There are a good chances that the help is rendered in time. Since in long-term heart examination huge amounts of data are generated it is needed an effective electrocardiogram (ECG) analysis algorithm. There are many ways to detect QRS-comlexes and other components. So in this paper major algorithms are presented. And it is described how it can be applied in real-time ECG analysis system.

Index Terms: MHealth, ECG, Arrhythmia.

I. Introduction

Modern electronics and telecommunications led to a significant step forward in the field of recording devices and the transmission of electrocardiograms (ECG). Hand held recorders give weight functionality for cardiologist and facilitate the daily lives of patients. One of the main reasons for the examination of patients using a personal recorder are complaints of cardiac origin. These include: palpitations, chest pain, dizziness, shortness of breath, tachycardia, sudden fatigue, arrhythmias, disruption of pacemaker.

Detection of some types of arrhythmias needs continuous monitoring of heart functions. Holter monitor used in Russian medicine is very uncomfortable since it is a heavy device and it requires skilled doctor's help. Consequently it can't be used for long term monitoring.

Recently, the more convenient solution is a usage of digital monitors. It the same time mobile devices like smartphones implement significant mathematical computations. It allows speeding up a processing of cardiodata and initial detection of heart problems.

This paper describes different algorithms for ECG analysis being applied in long term monitoring mobile system.

II. Algorithms for Analyzing Personal ECG

A. ECG Extraction

Electrocardiography (ECG) is a transthoracic interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded by a device external to the body.

The information is presented in fom of waves and time intervals between them. The waves in a normal record are named P, Q, R, S, and T and followeach other in alphabetical order. Fig. 1 shows normal segment of ECG. These waves usually repeat periodically. Any abnormal change in the shape and variation of time intervals are considered as arrhythmia [4].

On the other hand ECG is perceived as a set of numbers. Each number present value of amplitude. Consequently ECG can be processed by analysis algorithm [1].

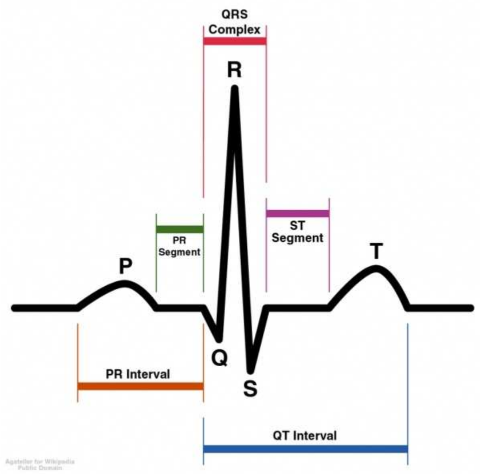

Fig. 1. Electrocardiogram

B. Real-time Mode Algorithms

Recently development of analysis algorithms on smartphones was greatly limited because of amount of memory and need to store large arrays of intermediate data. Now this problem is solved with the development of the hardware. Nevertheless the speed and efficiency of the algorithms are a key indicator for real-time systems of ECG analysis.

Therefore it is necessary for development an algorithm for analysis, which provides a classification of the ECG features in real-time mode. This algorithm must satisfy the following circumstances:

1) the minimum cost of computing power;
2) immunity to high noise;
3) an ability of the algorithm to classify the main ECG features;
4) R-peaks are the mail indicators of QRS-complexes.

At present there are many methods of ECG analysis, which can be divided into the following groups:

1) time-frequency methods;
2) methods based on neural networks;
3) syntactic methods;
4) methods of comparison with templates;
5) combined methods.

Time-frequency methods represent signal defined in the time domain in the form of an expansion in terms of orthogonal basis functions. Thus it is allocated frequency components. One of methods is the Fourier transform. But its drawback is that the frequency components can't be localized in time. These are limits of method's applicability. Wavelet transformations are more informative to investigate the dynamics of signal frequency changes [3].

The wavelet transformation allows to decompose analyzed signal on a compact, well-localized in time and frequency bases. It has a good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. This approach gives good results, especially when the signal components with high frequency have a short duration, and low-frequency components - large enough. The ECG signal, like most biological signals, is just such a structure [5].

Neural network techniques such as wavelet analysis have high noise immunity. They can construct fairly accurate analysis algorithms based on the detected lead. The disadvantage is the need for large computing resources [6].

Syntactic method analyzes the signal structure for syntactic rules. At the preliminary stage of the algorithm analyzing the structure of the signal zero-order interpolation and the formation of a succinct description of the signal can occur. Main characteristic elements of the ECG are determined by the description of the syntax signal. The effectiveness of the recognition algorithm is defined by syntactic rules and threshold values for the interpolation algorithms and concise descriptions that matched experimental logical way [7].

Structural recognition of signal is carried out by using the syntactic rules to define the basic elements of the ECG. The effectiveness of the recognition algorithm is defined by the rules and thresholds, which are selected by a logical development for each lead.

Method of templates implies a set of standards of classified pattern ECG complexes, which is comparedcwith the current track of ECG. Complexes classified as normal or reject template are stored in the memory of registration device [2].

C. Peculiarity of Implementation QRS detection algorithms

The starting point for a number of modern techniques of computer electrocardiography is the localization of QRS-complexes, which position is determined by the position of the maximum - R-peak. The resulting sequence of R-peak is used for segmenting of cardiac cycle, measuring the amplitude and duration of its individual elements. And also it is used to determine the contours of ECG using polynomial approximation and in the methods of analysis of heart rate variability.

ECG systems, which write and directly process the ECG signal during recording, are defined as real-time. Functional part of these systems must continuously process and analyze incoming information and quickly as possible with less delay, to respond to the changed state of the external parameters.

Because of these specific features of the ECG of a real-time high demands to the algorithms that implement the processing of incoming information. Among the most important requirements for such algorithms should be highlighted:

1) Corresponding to the performance of the algorithm speed of incoming data stream.
2) Warranty results or output control action for a predetermined period of time.
3) Ability to work effectively with the limited availability of input data.

The last requirement is essential for real-time systems, since its implementation requires certain qualities of the algorithm and can not be provided auxiliary hardware and software. Therefore, choosing a particular method requires a reasonable compromise between the functional characteristics of the method and the degree of compliance with the requirements of real-time. Thus, the task of choosing the optimal selection method QRS-complexes from the stream of incoming information for use in ECG real-time systems is quite important [2].

The proposed algorithm for detecting of QRS-complex is based on a number of the established methods. Technique allows reliable real-time mode to determine the position QRS-complexes.

The algorithm is divided into several steps:

1) Pre-treatment ECG, which consists of high-frequency (HF) and low frequency (LF) ECG filtering incoming traffic;
2) The calculation of two input data streams - a signal of the pre-processing, and signal further subjected to a number of non-linear transformations;

3) Calculation and comparison of adaptive thresholds, respectively, with two input streams;
4) Determination of the interval in which supposedly contains the R-peak.
5) Filtering incorrectly identified R-peak.

D. Analysis of Electrocardiogram

Normal values of ECG features and respective arrhythmia type are detected through ECG feature extraction using Wavelet Analysis [1].

One of technique of the detection of the QRS, T and P waves is Pan-Tompkins algorithm. The algorithm uses some of the basic techniques that are common in many pattern recognition systems. The ECG signal is first reduced into a set of predefined tokens, which represent certain shapes of the ECG waveform [2].

An algorithm based on first and second derivatives originally developed by Balda et al. (1977) was modified for use in high-speed analysis of recorded Electrocardiograms by Ahlstrom and Tompkins (1983). Friesen et al. (1990) subsequently implemented the algorithm as a part of the study to compare noise sensitivity among certain types of QRS detection algorithms.

The algorithm implements the detection of Normal beat segment, Tachycardia, Bradycardia, Sinus Arrhythmia, First-Degree Heart Block, Second-Degree Heart block, Ventricular Tachycardia, Ventricular Fibrillation and Ventricular Flutter. Pan-Tompkins algorithm and Wavelet transform allow to identifify ECG parametres. The algorithm consists of two parts: to extract Electrocardiogram's feature, and classify it. Figure 2 shows the procedure followed.

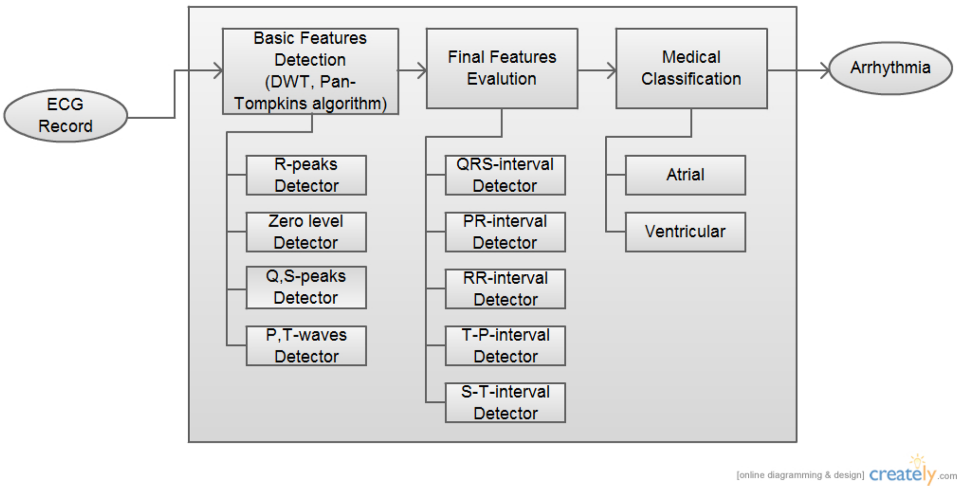

Fig. 2. Main algorithm

Pre-treatment of ECG is a step for filtering network noise in an area of 50/60 Hz and the noise of the electrical activity of muscles, which can be done quite effectively with a low purity filter (LPF).

The choice of filter is dictated primarily by computational load required efficiency and noise reduction. Adaptive filteringcan be proposed as an alternative solution.

Since the initial ECG contains a noise component having a low frequency (less than 1 Hz), it needs a correction of the ECG. It is possible to use various low-pass filters.

The next stage of the algorithm is to compute the adaptive thresholds. Two adaptive thresholds improve the efficiency of the method computes. They are used respectively to the two data streams. ne stream of data contains a signal of the pre-processing filtering. The second thread is a signal subjected to some nonlinear transformations.

The probability that the R-peak actually is contained in the intervals is quite high, but improvement of algorithm the accuracy requires the filtration procedure.It is incorrectly defined the positions R-peaks. This can be done tby use of heuristics analyze characteristics of an R-peak.

Next the location of the proposed R-wave properties of the array is created: from RR-interval duration between the study and the previous wave and the derivative signal, which is calculated at the point of the proposed R-peak. These parameters are stored in a circular buffer, which consists of least the last 3 values of R-peak, in addition to this we must compute the average heart rate for the last 10 cycles.

If the RR-interval between two successive peak is at least 300 ms, this corresponds to a pulse of 200 beats per minute. Hence the decision of choosing the true wave is driven by the maximum QRS-complex. Since that we know that R-prong has a maximum gradient.

This way to weed out the narrow and high R - and T-peak, often defined as a threshold detector R-tines. It is possible to further increase the efficiency of the algorithm with more complex heuristic analysis. This allows to adjust the algorithm without losing necessary QRS-complex during the follow-up.

III. Conclusion

Automatic detection of heart arrhythmias could be very important in clinical usage and lead to early detection of a fairly common malady and could help contribute to reduced mortality. Several stages of processing have been used in order to prepare the most appropriate arrhythmia classification.

The ECG detection which shows the information of the heart and cardiavascular condition is essential to increase the patient living quality and appropriate treatment. The ECG features can be extracter in time domain or frequency domain [8]. The extracted feature from the ECGsignal plays a vital in diagnosing arrhythmias. The development of accurate and quick method for automatic ECG features extraction of major impotance.

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