ПЛЕНАРНОЕ ЗАСЕДАНИЕ

UDC 616.12-073.97-71

A SYSTEM FOR AUTOMATIC PROCESSING, ANALYSIS AND CLASSIFICATION OF ECG CHARACTERISTICS TO DETERMINE VARIOUS STATES OF CARDIAC ANOMALIES

Magrupov T., Talatov Y., Magrupova M.

Tashkent State Technical University
Tashkent, Uzbekistan

Abstract. A systematic approach to the joint solution of problems of automatic processing, analysis, classification and measurement of characteristics of electrocardiogram signals is proposed, which ensures the elimination of one-sided solutions and organize a complex system consisting of various methods and algorithms. Algorithms have been developed for the proposed stages: preliminary processing, feature extraction, analysis of electrocardiograms, training, classification and recognition of characteristics of electrocardiograms, cardiac abnormalities, amplitude-time characteristics, diagnosis of diseases. A joint solution of discrete wavelet transform methods, artificial neural network, digital Butterworth filter, fast Fourier transform, Engelse and Zeelenberg segmentation, etc. All software products were implemented and tested using the MATLAB and PYTHON programming system.
Key words: automatic processing, electrocardiogram, cardiovascular disease, systems approach, neural networks.

СИСТЕМА АВТОМАТИЧЕСКОЙ ОБРАБОТКИ, АНАЛИЗА И КЛАССИФИКАЦИИ ХАРАКТЕРИСТИК ЭКГ ДЛЯ ОПРЕДЕЛЕНИЯ РАЗЛИЧНЫХ СОСТОЯНИЙ СЕРДЕЧНЫХ АНОМАЛИЙ

Магрупов Т., Талатов Я., Магрупова М.

Ташкентский государственный технический университет
Ташкент, Узбекистан

Аннотация. Предложен системный подход к совместному решению задач автоматической обработки, анализа, классификации и измерения характеристик сигналов электрокардиограмм, обеспечивающий исключение односторонних решений и организующий сложную систему, состоящую из различных методов и алгоритмов. Разработаны алгоритмы для предложенных этапов: предварительной обработки, выделения признаков, анализа электрокардиограмм, обучения, классификации и распознавания характеристик электрокардиограмм, нарушений сердечной деятельности, амплитудно-временных характеристик, диагностики заболеваний. Совместное решение методов дискретного вейвлет-преобразования, искусственной нейронной сети, цифрового фильтра Баттерворта, быстрого преобразования Фурье, сегментации Энгельса и Зеленберга и др. Все программные продукты были реализованы и протестированы с использованием системы программирования MATLAB и PYTHON.
Ключевые слова: автоматическая обработка данных, электрокардиограмма, сердечно-сосудистые заболевания, системный подход, нейронные сети.

Address for correspondence: Magrupov T., st. Universitetskaya, 2, Tashkent, Uzbekistan
e-mail: talatmt@rambler.ru

The development of computer, information and telecommunication technology around the world has opened new paths in the health care system during the prevention, diagnosis and treatment of diseases. Digitalization of healthcare is of great importance in conducting scientific and applied research and solving problems in this area.

In medical scientific research, during the registration, processing and analysis of biomedical signals (electrocardiogram, electroencephalogram, electromyogram, and others), there is a need to solve a large number of theoretical and practical problems due to the difficulty of formalizing and interpreting biomedical signals, which occupies the main and important place. This is due to the physiological origin of the signal, which determines its fuzziness, diversity, instability, unpredictability and tendency to numerous types of interference.

In medicine, among biosignals, the most informative and difficult to analyze and process is the electrocardiogram. When diagnosing various diseases (heart, neurological, oncological, etc.), the state of the cardiovascular system (CVS) is firstly determined. Correct and accurate processing and analysis of electrocardiograms allows timely and effective diagnosis of pathological changes in the cardiovascular system and determination of the type of cardiovascular diseases (CVD).

To date, many scientific and practical works have been published on the problems of CVD diagnostics, processing and analysis of the ECG signal [8–19]. On the basis of the analysis of existing works, it was concluded that the existing systems of automatic analysis do not make it possible to provide the required reliability of the results of diagnostics and diagnostic signs. Therefore, a systematic approach is required in the development of effective methods and algorithms for ECG processing and analysis for accurate and correct determination of the time and frequency parameters of the signal.

The proposed system for automatic processing, analysis and classification of ECG characteristics makes it possible to exclude unilateral decisions and organize a complex system consisting of various methods.

To achieve this goal, the following tasks are proposed:

– examine medical information to obtain correct or accurate information about the electrical potentials that are to be measured, determining changes in the physiological process in the patient;

– filtering and elimination of signal distortions (noise and artifacts) in the ECG signal. They usually appear when the object moves incorrectly during ECG registration, interference in the power line, improper installation of the electrode, and others;

– extraction of signs of the ECG signal, i. e. diagnostic medical information, determination of R-peaks and QRS complexes in the ECG signal;

– analysis of the characteristics of electrocardiograms, which consist in calculating the main characteristics of the ECG, heart rate;

– classification of ECG characteristics to determine various conditions of the cardiac system: myocardial infarction, bradycardia, tachycardia, premature ventricular contraction, normal state;

– measurement of the amplitude-time characteristics of the ECG based on the developed device.

The solution of these problems requires a systematic approach and is represented by a complex of algorithmic, hardware and software tools [13–17].

The paper proposes the stages of a system for automatic processing, analysis, classification and measurement of ECG characteristics to determine various states of arrhythmias for accurate diagnosis of diseases of the cardiovascular system (Figure 1).

The solution to the automation problem begins with the input of raw data provided by the medical institution or the open MIT-BIH Arrhythmia database, which contains raw ECG data. As you know, the received ECG signal has noises and artifacts and may be in the frequency band in which the study is being conducted and will distort the characteristics of the ECG signal.

To obtain a useful ECG signal, first of all, it is necessary to implement the pre-processing stage of the ECG signal.

The ECG signal preprocessing stage is designed to extract medical information about the useful signal based on the initially specified noisy ECG signals from the database. To obtain the true state of the signal, you must first process the specified ECG signal. In this case, it is required not to eliminate vital signs, i. e. characteristics of the ECG signal. An algorithm for preprocessing the ECG signal is proposed. To remove noise on the power line at 60 Hz, a Butterworth bandpass filter with a cutoff frequency of 59 Hz and 61 Hz is used. To do this, first the ECG signal is standardized and reduced to a mean value so that it is centered around zero. This is achieved using MATLAB.

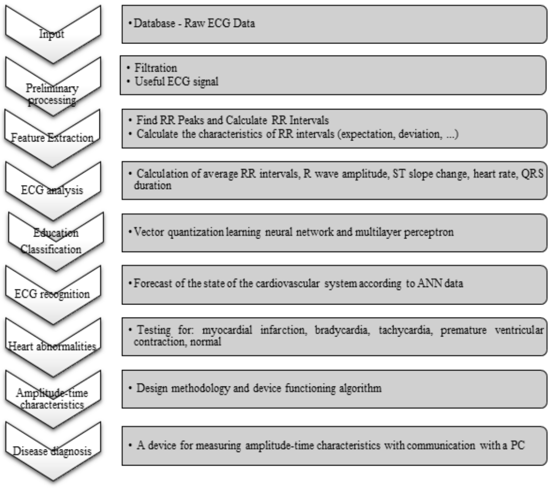

Figure 1 – Stages of a system for automatic processing, analysis, classification and measurement of ECG characteristics to identify various states of cardiac abnormalities

Two methods of removing baseline wandering are investigated and their effectiveness is determined. The results show that when filtering the ECG, the Butterworth filter retains the required characteristics in the filtered time domain. The wavelet transform sets the approximation coefficients to zero and hence the baseline offset is determined by low pass filtering. In this case, a Daubechies6 wavelet with a level of 8 was used because of its shape, similar to the ECG signals. To eliminate other broadband noises, a high-level discrete wavelet transform with maximum overlap is used. As a result, we will receive a useful ECG signal for further processing.

At the stage of feature extraction, the Q, R, S peaks of the QRS complex and the state of the ST segment tilt are detected based on the Pan-Tompkins method. On the basis of determining the number of peaks R and dividing it by a given time, the calculations of the RR interval, the amplitude of the R wave, the duration of the QRS complex and the slope of the ST segment, the heart rate and the detection of violations were made. Determined that the Pan-Tompkins method gives better results in relation to other methods.

At the next stage, the analysis of the characteristics of the electrocardiograms, the mean values were calculated: RR intervals, R wave amplitude, changes in ST slope, QRS complex duration, heart rate for each ECG beat.

At the next stage, the analysis of the characteristics of the electrocardiograms is carried out to calculate the average RR intervals, the R wave amplitude, changes in the ST slope, the duration of the QRS complex, the heart rate for each ECG beat.

The next step is to classify the characteristics of the ECG to identify cardiac abnormalities. For this, training is offered: vector quantization training neural network. They are used to classify ECGs and identify diseases: tachycardia, bradycardia, PSG, myocardial infarction, or no disease. In this case, each average value of five functions will represent five inputs in the vector quantization learning neural network. In accordance with the type of disease, output parameters or target classes are defined for each ECG signal function. To determine the appropriate target class, depending on the value of the functions, a decision tree is generated for each signal. After training and testing the vector quantization learning neural network, the classification model is evaluated. Generating a multilayer perceptron based neuroclassifier requires a labeled dataset that provides the correct class for each sample. The labeled dataset is divided into a training dataset with which the neural network is trained to obtain the actual classification of the data and a test dataset to evaluate the performance of the network. The minimum distance classifier will be used as the decision rules that will allow classifying the types of arrhythmias in the vector space. The essence of the method is that there are m reference vectors V_1, V_2, ..., V_m in the n-dimensional feature space. Each vector serves as a reference (template) of its class and is defined as $V_i = (V_1, V_2, ..., V_n)$ corresponding to the class W_i.

The proposed neuroclassifier determines whether the input vector X belongs to the class W_i for which the distance between X and the reference vector V_i is minimal.

At the stage of ECG recognition, the forecast of the state of the cardiovascular system is carried out according to the data of an artificial neural network. Methods for preparing parameters of heart rate variability, which characterize a series of periods of heart contractions and are used as an indicator of the states of the cardiovascular system to determine the diagnostic functions of the ECG, are presented.

The stage of cardiac abnormalities is testing for: myocardial infarction, bradycardia, tachycardia, premature ventricular contraction, normal state based on the proposed algorithms of the vector quantization neural network learning and multilayer perceptron. The efficiency of the preferred neural network model with extended functions for the classification of ECG signals is calculated, taking into account various possible ECG states.

The stage of measuring the amplitude-time characteristics is implemented by the proposed device for measuring the amplitude-time characteristics of electrocardiographic biopotentials, electroencephalographic, electromyographic studies for monitoring the functional state of the patient and diagnosing pathologies her health, as well as improving the methods of their registration. Removing and analyzing the amplitude and time characteristics of the ECG signal is necessary for automatic interpretation of the ECG to identify pathological changes in the cardiovascular system.

The final stage determines the diagnosis of diseases using a device for measuring amplitude-time characteristics with communication with a PC. A design technique and an algorithm for the operation of the device are proposed.

For the organization of the system of automatic processing, analysis and classification of ECG characteristics and determination of various states of the cardiovascular system, it is important to use and jointly solve the methods of discrete wavelet transform, artificial neural network, digital Butterworth filter, fast Fourier transform, Engelse and Zeelenberg segmentation and other.

The algorithms developed on their basis have been implemented and will be improved using the MATLAB and PYTHON programming systems.

The proposed methods, algorithms, devices and software for automatic processing, analysis and classification of ECG characteristics to determine various states of the cardiovascular system are intended to analyze the heart rate and, accordingly, dynamic changes in the ECG. a type of heart abnormality. The proposed complex of algorithms and software system for processing, analysis, ECG classification and measurement of amplitude-time characteristics of biopotentials are new and have a fairly high sensitivity of 92 %, and the specificity was 89 %. Together, this shows a high indicator of the classification accuracy and is more acceptable for use in the diagnosis of cardiovascular diseases – arrhythmias. All software products were implemented and tested using the MATLAB and PYTHON programming systems.

References

1. Рангайян, Р.М. Анализ биомедицинских сигналов. Практический подход / Р.М. Рангайян; под ред. А.П. Немирко. – М. : Физматлит, 2010. – 440 с.
2. Съем и обработка биоэлектрических сигналов: учебное пособие / К.В. Зайченко [и др.]. – СПб. : ГУАП, 2001. – 140 с.
3. Истомина, Т.В. Методы и средства обработки биоэлектрической информации / Дисс. д.т.н. – Пенза, 2002. – 172 с.
4. Калиниченко, А.Н. Компьютерные методы автоматического анализа ЭКГ в системах кардиологического наблюдения / Дисс. д.т.н. – СПб., 2008. – 182 с.
5. Немирко, А.П. Математический анализ биомедицинских сигналов и данных / А.П. Немирко, Л.А. Манило, А.Н. Калиниченко. – М. : ФИЗМАТЛИТ, 2017. – 248 с.
6. Сушкова, Л.Т. Автоматизация медико-биологических и экологических исследований на основе цифровой обработки информации / Дисс. д.т.н. – Владимир, 1999. – 137 с.
7. Pan, J. A real-time QRS detection algorithm / J. Pan, W.J. Tompkins // IEEE Trans. Biomed. Eng. – 1985. – Vol. 32. – P. 230–236.
8. Трешкур, Т.В. Электрокардиографические особенности автоматических идиовентрикулярных ритмов / Т.В. Трешкур // Вестник аритмологии. – 2005. – № 38.
9. ECG beat detection using filter banks / V.X. Afonso [et al.] // IEEE Transactions on Biomedical Engineering. – 1999. – Vol. 46. – № 2. – P. 192–202.

10. Trahanias, P.E. An approach to QRS complex detection using mathematical morphology / P.E. Trahanias // IEEE Trans. Biomed. Eng. – 1993. – Vol. 40, №. 2. – P. 201–205.

11. Леонова, А.В. Модификация алгоритма распознавания QRS комплексов в реальном времени Пана-Томпкинса / А.В. Леонова, А.А. Агейченко // Инженерный вестник Дона. – 2015. – № 2. – С. 72–76.

12. Юлдашев, М. Многоуровневая интеллектуальная система удаленного мониторинга состояния здоровья людей с хроническими заболеваниями / М. Юлдашев, Е.А. Пустозеров, А.А. Анисимов // Приборостроение, метрология и информационно-измерительные приборы и системы. – 2016. – № 5. – С. 2–8.

13. Magrupov, T.M. ECG processing and analysis technique based on neural network learning vector quantization / T.M. Magrupov, Sh.K. Nematov, Y.T. Talatov // Chemical Technology, Control and Management. – 2020. – Iss. 4, Article 3. – P. 15–22.

14. Talatov, Y.T. Algorithmic and software analysis and processing of ECG signals / Y.T. Talatov, T.M. Magrupov // Conference Proceedings. SIBIRCON 2019 – International Multi-Conference on Engineering, Computer and Information Sciences, Proceedings. – 2019. – P. 403–406.

15. A Technique for Classifying the ECG Signal into Various Possible States of the Cardiovascular System / Y.T. Talatov [et al.] // Conference Proceedings. 2020 IEEE International Conference on Electrical Engineering and Photonics (EExPolytech). – 2020. – P. 127–131.

16. Talatov, Y.T. A Device for Measuring of Frequency Response Function of Biopotentials / Y.T. Talatov, T. Magrupov, A. Radjabov // Conference Proceedings. SIBIRCON 2019 – International Multi-Conference on Engineering, Computer and Information Sciences, Proceedings. – 2019. – P. 7–10.

17. Methodology for processing and analysis of diagnostic indicators electrocardiogram based on Labview / Y.T. Talatov [et al.] // 2020 International Conference on Information Science and Communications Technologies, ICISCT 2020. – 2020. – P. 9351478.

18. An ECG Processing and Analysis Technique Based on Neural Network / Y.T. Talatov [et al.] // International Conference on Information Science and Communications Technologies, ICISCT 2020. – 2020. – P. 9351478.

19. Talatov, Y.T. A method for classifying ecg signals with different possible states on a multilayer perceptron / Y.T. Talatov, Sh.K. Nematov // Technical Science and Innovation. – 2020. – № 4. – P. 71–79.

УДК 531.383

ПОГРЕШНОСТИ БЕСПЛАТФОРМЕННЫХ ИНЕРЦИАЛЬНЫХ НАВИГАЦИОННЫХ СИСТЕМ

Матвеев В.В.

ФГБОУ ВО «Тульский государственный университет»
Тула, Российская Федерация

Аннотация. Рассматриваются погрешности бесплатформенных инерциальных навигационных систем (БИНС), вызванные инструментальными погрешностями датчиков первичной информации. Приводятся соотношения для оценки средних квадратических отклонений погрешностей БИНС, вызванных шумом гироскопов и акселерометров. Даны оценки погрешностей БИНС на коротком интервале времени для уровня шума микромеханических датчиков первичной информации.
Ключевые слова: бесплатформенная инерциальная навигационная система, гироскоп, акселерометр, погрешность.

ERRORS OF STRAPDON INERTIAL NAVIGATION SYSTEMS

Matveev V.V.

Tula State University
Tula, Russian Federation

Abstract. Errors in strapdown inertial navigation systems (SINS) caused by instrumental errors in primary information sensors are considered. Relations are given for estimating the standard deviations of SINS errors caused by the noise of gyroscopes and accelerometers. Estimates of SINS errors over a short time interval are given for the noise level of micromechanical sensors.
Key words: strapdown inertial navigation system, gyroscope, accelerometer, error.

Адрес для переписки: Матвеев В.В., пр. Ленина ,95, г. Тула, 300012, Российская Федерация
e-mail: matweew.valery@yandex.ru

Введение. Сегодня не вызывает сомнений вопрос о перспективности использования бесплатформенных инерциальных навигационных систем (БИНС) на подвижных объектах наземного, морского и воздушного базирования [1; 2]. БИНС не требуют информации о магнитном поле Земли, местоположении небесных светил, ветровых и морских течений. Координаты местоположения подвижного объекта в БИНС определяются автономно на основе показаний гироскопов и акселерометров. Основная идея инерциальной навигации – это двойное интегрирование измеренных акселерометрами ускорений. Гироскопы служат для обеспечения информацией об угловой ориентации измерительных осей акселерометров путем численного интегрирования кинематических уравнений.