3-бөлім	Раздел 3	Section 3
Информатика	Информатика	Computer science

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Data processing in electrocardiographs by wavelet transformation for early forecasting of parossysmal arthritis

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ECG analysis is widely used to diagnose many heart diseases, which are the leading cause of death in different countries. The quality of the ECG signal can be affected and worsened by various sources, such as the patient's condition, basic walk, electrocardiogram contact, and others. In addition, if the ECG is visually monitored, the probability of human error is high, each 10-result is interpreted with an error (Brikena Xhaja, 2015: 305-312) And also for many ECG images it is simply not possible to conduct a visual analysis of the frequency data of the signal. The morphology of low-amplitude high-frequency signals, the so-called P waves, hides valuable information for early preclinical disease prediction. That is, the need to search for new methods of early preclinical diagnosis is still relevant. Since the majority of clinically useful information in the ECG is found in the intervals and amplitudes determined by its significant points (characteristic peaks and wave boundaries), the development of accurate and reliable methods for automatic ECG delineation is a matter of great importance, especially for the analysis of long records (Juan Pablo Martinez, 2014: 570-581). The problems of retrieving information from the electrophysiological signal that can not be obtained by visual analysis of the recording, as well as the problems of automation of traditional algorithms of medical analysis are relevant in connection with the lack of research in this field. The aim of the research is to search for new areas of application of the wavelet transform method in signal processing. Wavelet transformation, obtained widely in 2000 in the study of signal properties, allows us to "discern"hidden frequency-time signal data with the help of approximating and detailing coefficients. The obtained results show that the proposed algorithm provides real efficiency in the processing of primary signals for the task of isolating the detailing coefficients of the ECG signal. Our study shows that Morlet's wavelet analysis of P intervals, which can be applied easily and inexpensively, can reliably predict the incidence of symptomatic episodes of paroxysmal atrial fibrillation in patients without clinically and echocardiographically expressed heart disease. Wavelet analysis can contribute to our understanding of the electrophysiological mechanisms underlying the generation and recurrence of paroxysmal atrial fibrillation and can identify patients at high risk of increased relapses of paroxysmal atrial fibrillation, thereby creating the prospect of early application of non-invasive and invasive therapeutic strategies to prevent future events of paroxysmal ciliary arrhythmias.

Key words: electrocardiogram, wavelet transformation, paroxysmal atrial fibrillation.

Пароксизмалды аритмияны ерте болжауды зерттеу үшін вейвлет түрлендіру әдісін электрокардиограммалардағы мәліметтерді өңдеуде қолдану

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Көптеген елдерде өлімнің басты себебі болып табылатын жүрек ауруларын болжау үшін ЭКГ талдауы кеңінен қолданылады. ЭКГ сигналының сапасы түрлі себептерден нашарлауы мүмкін, оған емделушінің күй-жағдайы, ЭКГ электродтарының байланысы сияқты себептер жатады. Одан басқа, егер ЭКГ бейнесі визуалды түрде интерпретацияланатын болса, онда адами қателікке ұрыну ықтималдығы жоғарылай түседі және статистикалық мәліметтер бойынша визуалды талданған ЭКГ бейненің әр оныншысы қате интерпретацияланады (Brikena Xhaja, 2015: 305-312). Сонымен қатар көптеген ЭКГ бейнелер арқылы сигналдың жиіліктік мәліметтері туралы ақпаратты визуалды түрде жүргізуге болмайды. Төмен амплитудалы жоғары жиілікті сигналдардың морфологиясы көптеген ауруларды алдын ала болжауға қолданылатын құнды мәліметтерге ие. Сондықтан ерте клиникалық болжаудың жаңа әдістерін іздеу қажеттілігі әлі де өзекті мәселе. ЭКГ бейнесіндегі пайдалы ақпараттың көпшілігімаңызды нүктелерімен анықталатын интервалдар мен амплитудаларда орналасқандықтан, ЭКГ-да осы аймақтарды нақты және сенімді бөлетін автоматты әдістерді өңдеу өте маңызды мәселе болып табылады, әсіресе ұзындығы шамалы болатын жазбаларда(Juan Pablo Martinez, 2014: 570-581). Электрофизиологиялық сигналдардан визуалды түрде алуға болмайтын ақпаратты алу мәселелері, сонымен қатар дәстүрлі дәрігерлік талдауды автоматтандыру мәселелері осы облыстағы зерттеулердің аздығынан өзекті болып табылады. Зерттеудің мақсаты сигналдарды өңдеуде вейвлет түрлендіру әдісін қолданудың жаңа бағыттарын іздеу болып табылады. 2000 жылдары сигналдың қасиеттерін зерттеуде кеңінен қолданыла бастаған Wavelet трансформациясы бізге аппроксимация және бөлшектеу коэффициенттері арқылы жасырын жиілік сигналының деректерін «айырып» алуға мүмкіндік береді. Алынған нәтижелер көрсеткендей, ұсынылған алгоритм ЭКГ сигналының егжей-тегжейлі коэффициенттерін оқшаулау мақсаты үшін бастапқы сигналдарды өңдеуде нақты тиімділікті қамтамасыз етеді. Біздің зерттеуіміз көрсеткендей, Морлет вейвлетін қолданумен P аралықтарын талдауда оңай және арзан түрде қолдануға болатын клиникалық және эхокардиографиялық жүрек ауруымен ауыратын науқастарда пароксизмальды атриальді фибрилляцияның эпизодтарының симптомдық эпидемиясын сенімді болжауға болады. Вейвлет талдауы пароксизмальды атриальді фибрилляцияның генерациясы мен қайталануын негіздейтін электрофизиологиялық механизмдерді түсінуге ықпал ете алады және пароксизмальды атриальді фибрилляцияның қайталануының жоғарылауы жоғары емделушілерді анықтай алады, осылайша, пароксизмалы шырышты болашақ оқиғалардың алдын алу үшін инвазивті емес және инвазивтітерапевтік стратегияларды ертерек қолдану мүмкіндік береді.

Түйін сөздер: электрокардиограмма, вейвлеттік түрлендіру, пароксизмалды аритмия.

Обработка данных в электрокардиограммах методом вейвлетного преобразования для исследования раннего прогнозирования пароксизмальной мерцательной аритмии

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Анализ ЭКГ широко используется для диагностики многих сердечных заболеваний, которые являются основной причиной смертности в разных странах. Качество сигнала ЭКГ может быть затронут и ухудшен различными источниками, такими как состояние пациента, базовое блуждание, контакт электродов ЭКГ и другие. Кроме того, если ЭКГ контролируется визуально, вероятность получения человеческой ошибки высок, каждый 10-результат интерпретируется с ошибкой (Brikena Xhaja, 2015: 305-312). А также по многим ЭКГ снимкам просто не возможно провести визуальный анализ частотных данных сигнала. Морфология низкоамплитудных высокочастотных сигналов, так называемых P волн, скрывает ценную информацию для раннего доклинического прогнозирования болезней. То есть необходимость поиска новых методов ранней доклинической диагностики все еще актуальна. Поскольку большая часть клинически полезной информации в ЭКГ обнаруживается в интервалах

и амплитудах, определяемых ее значимыми точками (характерные пики и границы волн), разработка точных и надежных методов автоматического разграничения ЭКГ является предметом серьезной важности, особенно для анализа длинных записей (Juan Pablo Martinez, 2014: 570-581). Проблемы извлечения из электрофизиологического сигнала информации, которую невозможно получить при визуальном анализе записи, а также проблемы автоматизации традиционных алгоритмов врачебного анализа являются актуальными в связи с недостатком исследований в данной области. Целью исследования является поиск новых областей применения метода вейвлетного преобразования в обработке сигналов. Получившее широкое распространение в 2000 годах в исследовании свойств сигналов вейвлетное преобразование позволяет с помощью аппроксимирующих и детализирующих коэффициентов «разглядеть» скрытые частотно-временные данные сигнала. Полученные результаты показывают, что предлагаемый алгоритм обеспечивает реальную эффективность в обработке первичных сигналов для задачи выделения детализирующих коэффициентов ЭКГ сигнала. Наше исследование показывает, что вейвлет-анализ Морлета интервалов Р, который применять легко и недорого, может достоверно предсказать частоту симптоматических эпизодов пароксизмальной мерцательной аритмии у пациентов без клинически и эхокардиографически выраженной болезни сердца. Вейвлет анализ может способствовать нашему пониманию электрофизиологических механизмов, лежащих в основе генерации и рецидивов пароксизмальной мерцательной аритмии, и может позволить идентифицировать пациентов с высоким риском увеличения рецидивов пароксизмальной мерцательной аритмии, тем самым создавая перспективу раннего применения неинвазивных и инвазивных терапевтических стратегий для предотвращения будущих событий пароксизмальной мерцательной аритмии.
Ключевые слова: электрокардиограмма, вейвлетное преобразование, пароксизмальная мерцательная аритмия.

1 Introduction

The quality of the ECG signal can be affected and worsened by other sources, such as the patient's condition, the underlying walk and the patient's weakness. contact of ECG electrodes. In addition, if the ECG is visually monitored, the probability of human error is high, each 10-result is interpreted with an error(Brikena Xhaja, 2015: 305-312). A typical ECG trace of a normal heart rhythm consists of a P-wave, a QRS complex, a T wave, which is shown in Figure 1:

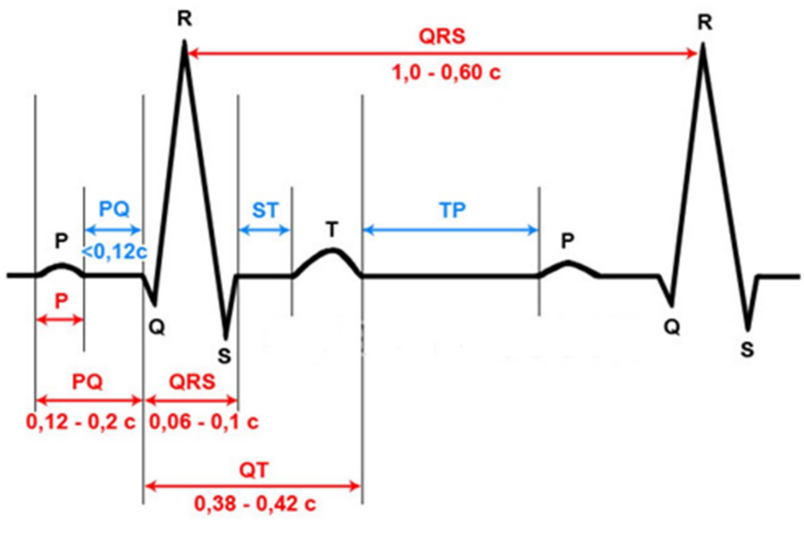

Figure 1 - ECG trace(www.okardio.com)

We can see that the peaks of the QRS complexes are smoothed out, and the P- and T-waves containing the lower frequencies become more noticeable. The determination of the position of the wave P and wave T is complicated because of its small amplitude. At the same time, we can also find that parts on a lower scale make up higher signal frequencies. In this paper, attention is focused on the wave P. The advantage of the wavelet transform lies in its ability to extract the details of the ECG signal with optimal temporal resolutions. Information on the complex P obtained is very useful for ECG classification, analysis, diagnosis, authentication and identification. The main advantage of this kind of detection is a shorter time for a long-term ECG signal (Gautam A., 2012: 632-635). The method based on the wavelet transform can be used to determine the characteristic characteristics of the ECG signal with fairly good accuracy even in the presence of high-frequency and low-frequency noise (P.Sasikala, 2011: 489-493). The presentation of the work done consists of the following sections. The "Literature overview"section contains an overview of related works devoted to the application of wavelet transform methods to extract the detail data contained in the signals. In the section "Materials and methods"the essence of the problem is stated and the general steps of its solution are indicated. And as the specified steps are specified and specified in the form of a new way of data extraction. The "Main results"section describes the results obtained using the proposed method. Conclusions formulate conclusions and provide a plan for future research.

2 Literature review

Information hidden in the P interval, which has a low amplitude and a high frequency of distribution, is often equally important for research than high-amplitude bursts and harmonics. The interval P has a duration of 0.11 seconds, a positive value of the amplitude (Chazov M., 2014:1). A specialist in the interpretation of ECG, mainly draws attention to these two parameters, and a deep study of this interval and its morphology often remains without due attention. Ignoring the high frequencies and its content in the P interval may lead to an omission of early preclinical prediction of some kind of heart disease. For this reason, the task of extracting hidden parts is of high relevance, but in the literature it is not given enough attention. In (Grigoriev D.S., 2012:57-61), the morphology of the PQRST complex for deep study of arrhythmia and normal sinusoidal rhythm was also studied using wavelet methods, namely, the Daubechies wavelets. In article (K.Venkata, 2011:60-69), pathologies associated with QRS changes were investigated using a discrete wavelet transform. Further, the works of these authors were concentrated on the interval T and new data were revealed in ECG signals, these data were used for early preclinical detection of some pathologies. For early preclinical detection of cardiac pathology, no study is given for the P interval. Recently, several research algorithms have been developed to detect arrhythmia in ECG signals, some of which use wavelet transformation, fuzzy logic methods, reference vector machines with an approach that demonstrates their advantages and disadvantages. In (Ivanko E.O., 2009: 160-164), a continuous wavelet transform was used to extract traits from the ECG signal to determine late atrial potentials, this algorithm achieves a positive predictability of 98Thus, in this review, we examined the 7 most interesting articles of processing ECG data by wavelet transformation methods. All these methods are heuristic, i.e. based on the assumptions regarding the nature of signal distribution in the time domain of the distribution. A comparative analysis of these statements shows that there are both coincidences of the positions of different authors and serious discrepancies, which indicates that there are unresolved problems in this area.

3 Materials and methods

At present, in connection with the increase in the number of patients with paroxysmal atrial fibrillation, there is an urgent need to search for new methods of early preclinical diagnosis. These methods should meet a number of requirements: to have a sufficiently high sensitivity and specificity, the possibility of using in outpatient settings and low time and financial costs in conducting screening studies. The method of the standard ECG and the carrying out of exercise tests have by now reached certain limits of their diagnostic capabilities for the detection of hidden PMA of the heart. In its initial stages, the use of conventional electrocardiography, as a rule, does not reveal abnormalities. At the same time, there is reason to assume that already in this period there are changes in the frequency and temporal characteristics of the electrical potentials of the heart that are not recorded with the help of a conventional electrocardiograph. Fundamentally new possibilities are opened when modern mathematical methods of analysis are applied to the ECG signal, based on signal representations in the form of expansions in some generalized vector spaces. The most famous example of such an expansion is the Fourier transform, realized most often as a Fast Fourier Transform (FFT). Let $f(x)$ — continuous function of a real variable x . The Fourier Transform of a function

$f(x)$ is defined by equation:

$$F(U) = \int_{-\infty}^{\infty} f(x)e^{-i2\pi ux}dx \tag{1}$$

where $i = \sqrt{-1}$ and u often called a frequency variable. Summation of sines and cosines may not be so obvious at first glance, but applying Euler's equation, we get:

$$F(U) = \int_{-\infty}^{\infty} f(x)(\cos 2\pi ux - i\sin 2\pi ux)dx \tag{2}$$

For this $F(u)$, we can go back and get $f(x)$ using the inverse Fourier Transform:

$$f(x) = \int_{-\infty}^{\infty} F(U)e^{-i2\pi ux}dx \tag{3}$$

The application of a temporary "window"allows estimating the change in the signal spectrum in different phases of a cardiocycle. This method is called Spectral-temporal mapping. This technique has now become quite widespread. At the same time, all the potential capabilities of the CRM method remain unfulfilled in it, primarily due to the natural shortcomings of the standard Fourier analysis. The fact is that the method uses a fixed "window"that can not be adapted to local signal properties. As a result, in the low-frequency part of the spectrum, the frequency resolution is lost, and the frequency resolution is lost in time. To resolve this contradiction in modern mathematics, a number of methods for analyzing non-stationary signals have been developed (this class includes ECG signals). The most famous was the so-called wavelet transform (Wavelet-transform). It represents the decomposition of a signal over a set of basis functions, which are determined on an interval shorter than the duration of the cardiac signal (www.okardio.com).

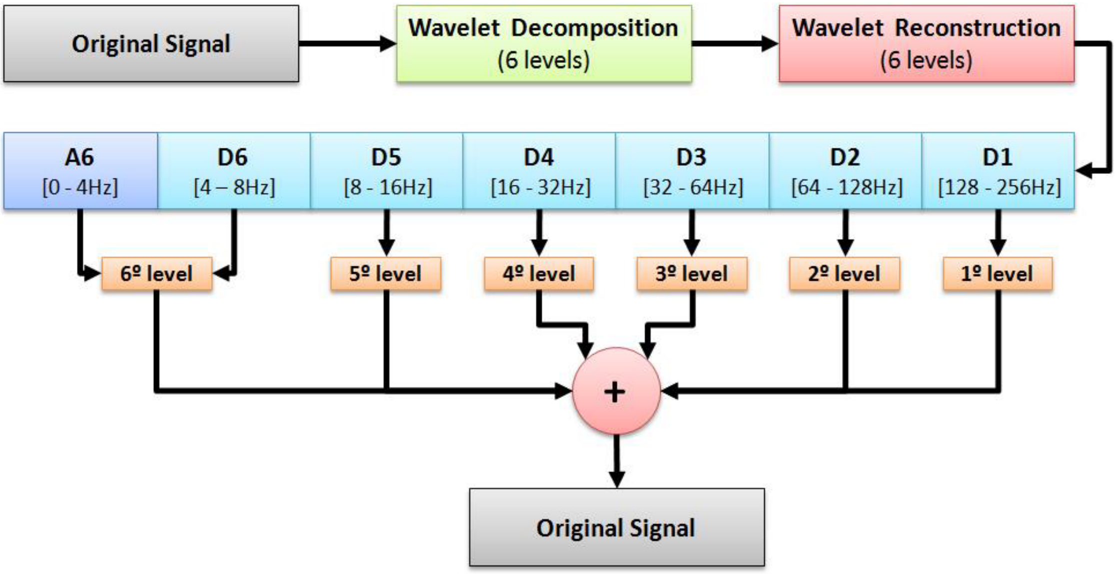

Figure 2- 6-leveled wavelet decomposition

In this case, all functions of the set are generated by means of a two-parameter transformation (a shift along the time axis and a scale change) of one initial function, called the "parent"function. They are called wavelets (in translation - short waves or bursts). Large values of the scale parameter correspond to the application of the low-pass filter to the original signal, small values of the high-pass filter. From the Fourier transform, the wavelet transform differs in that the multiplication by the "window"is contained in the very basic function, and the "window"adapts to the signal when the scale is changed (Dobesi I.,2001:464). This module computes a wavelet analysis using different types of wavelets. In STx a scaled wavelet transformation with a bounded integration interval is used:

$$H(a,b) = \frac{1}{aS(a)} \int_{-\alpha}^{\alpha} h(t)W(\frac{t-b}{a}, f0)dt \quad (4)$$

with:

a frequency scaling parameter b time shift parameter S(a) amplitude scaling factor a time window width (input ACUT) f0 basic frequency of wavelet function (input F0) For the study, we used the results of ECG images of 2000 patients who were presented by the Almaty Cardiology Center and were taken from the site (Open MIT ECG Database, 2012) with episodes of symptomatic paroxysmal arrhythmia (PMA) from January 2017 to December 2017 and were taken with Edan SE-3 devices, EXT 01-R-D. Of these, 500 patients had the first episode, and 500 had a relapse of the PMA episode. Patients were observed 12 months and classified into three groups depending on the number of PMA relapses per year: group A - healthy patients without recurrence of PMA, with less than five relapses per year - group B and with more than five relapses per year - group C.

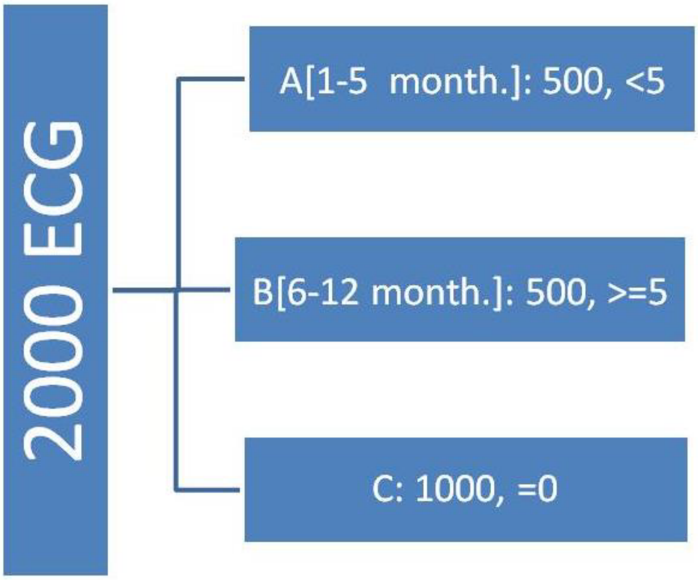

Figure 3 - Study groups

Although Group B and Group C patients did not differ in time in AF, Group C patients had more PMA episodes in their medical chart, these episodes were longer and the time in the sinus rhythm before the last episode of PMA was larger compared to patients in Group B. All subjects were subjected to ECG analysis, as described below, at the initial and subsequent levels.

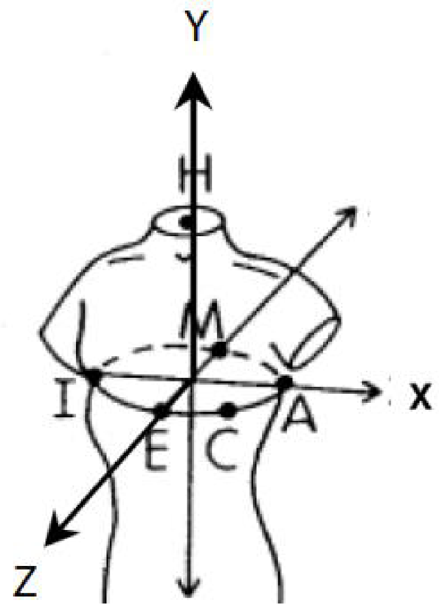

Figure 4 - Leads [12]

The wavelet transform was proposed as an alternative way to analyze non-stationary biomedical signals, which decompose the signal into basic functions. The wavelet method acts as a mathematical microscope, in which we can observe different parts of the signal simply by adjusting the focus (Boytsov S.A., 2001:32-34). The usual application of wavelet methods for processing medical waves uses a wavelet transformation based on the use of a single wavelet, rather than on the basis of a set constructed from a family of mathematically related wavelets. Again, choosing a wavelet with appropriate morphological characteristics with respect to the physiological signal under consideration is critical to the success of the application. Next, various DWT applications will be presented in cardiac studies with interesting applications such as noise cleaning and compression of medical signals, segmentation of the electrocardiogram (ECG) and the derivation of latent characteristics, heart rate variability analysis and analysis of various cardiac arrhythmias.

4 Main results

The use of the method for the three groups showed the following results: Mean and Max values correspond to the area and maximum peak value of P., respectively. Observations showed that there was no special difference between groups of patients and healthy in the lead X. In lead Y as well, there was no difference between the maximum values of healthy and sick, and the areas were not. In lead Z there were differences between the data of groups A, B and C. As the results of the wavelet transformation showed, the patients of group C had a larger value of P both in area and in the maximum value of peak P. The duration of wave P increased in patients with any number of repetitions disease.

5 Conclusion

The algorithm of processing data based on the wavelet transformation of the signal was presented in the paper. The main idea was to process the data - signals, for its subsequent processing. The obtained results show that the proposed algorithm provides real efficiency in the processing of primary signals for the task of isolating the detailing coefficients of the ECG signal. The development perspective of this approach is the development of software modules that allow you to configure the transformation parameters in the user interface, as well as the improvement of the algorithm itself. The present approach and results can be implemented in the ecg machines to provide an analytical report along with the patient's ECG. Accurate and reliable ECG analysis in the ECG machine is very much in demand today. The efficiency of the developed diagnostic method was proved on the basis of numerical experiments. The next stage in the development of the system will be optimization and testing on longer signals to diagnose a wider range of diseases.

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