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IMPROVEMENT OF THE CREDIBILITY OF ANALYSIS OF ELECTROCARDIOGRAMS FOR BIOMETRIC PERSONAL IDENTIFICATION

Nowadays there is a high demand for biometric authentication. These systems possess a high level of protection, as they evaluate not only the physical parameters, but also personality characteristics. The paper analyzes a biometric scheme based on the electrical activity of the human heart in the form of electrocardiogram (ECG) signals. The study was performed using standard laboratory measurements KL-720 has all age groups. As a result, an electrical activity signal was obtained. The aim of this work was to filter the captured signal for further use with biometric data.
Key Words: *electrocardiogram, biometric identification, authentication, ECG parameters, high-frequency noise, low-frequency noise, Z-scaling, HPF Butterworth.*

Currently identity authentication is carried out using biometric methods, as biometric access control systems are convenient for users in that the necessary information is always with them and cannot be lost, stolen, or falsified. Such access control is more reliable since identifiers cannot be transferred to third parties or copied to bypass the security system [1].

Existing methods of personal identification (Fig. 1) are divided into static, which are constant in time, and dynamic, in which, according to biometric properties, the measurement process takes some time which is necessary to find personal characteristics. Despite the advantage of the presented methods, there is still a risk of obtaining information by third parties. As the identification by face is easy to get around by the photograph, there is a similar method which uses the iris of the eye, though it is quite inconvenient [1,2]. The fingerprint identification method is used by most people on smartphones daily, however it is not safe enough to protect important and confidential information by this method, since it is easy to make a mold and make a fingerprint model which allows to bypass the system easily.

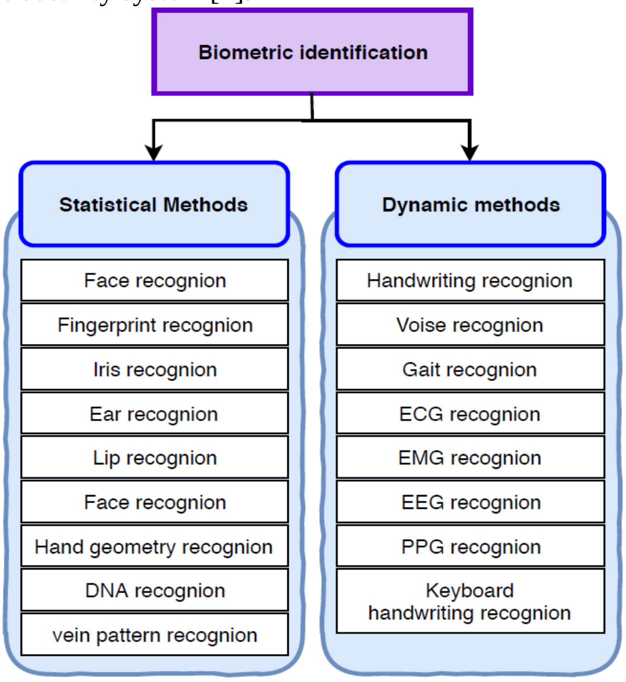

Fig.1. Classification of biometric personality identification.

The prevention of fatal errors associated with personal identification in medical institutions is extremely important, as it is important to determine the identity of the patient before any medical manipulation. For such purposes the physical access control system (PACS) is used to identify an individual and automatically provide access to information. Unfortunately, there is no legislative document on the implementation of the identification process. This means that it is very important to develop a local patient identification algorithm. To choose a method with a lower cost of expenses but with sufficient accuracy in determining the identity, it is necessary to compare each of the possible ones. Table 1 shows a comparison of the methods for the main parameters [1-3].

FAR (False Acceptance Rate) - false pass coefficient, i.e. the percentage of cases, in which the system allows access to a user who is not registered in the system.

FRR (False Rejection Rate) - false failure rate, i.e. denial of access to the real user of the system.

The falsification of biometric data for obtaining information and control is a complex process, which is possible with special preparation and special technical support. Based on this, it was proposed to use a signal of electrical activity of the heart. Since the electrical activity of each person is unique, it is possible to use an ECG as a biometric parameter in various identification systems with a high degree of protection.

Table 1

Comparison of biometric identification methods

Biometric PACS uses	FAR %	FRR %	Falsification	Invariance of characteristic	Sensitivity to external factors	Speed of authentication	Price
Fingerprint	0,001	0,6	Possible	Low	High	High	Low
Face Recognition 2D	0,1	2,5	Possible	Low	High	Average	Average
Face Recognition 3D	0,0005	0,1	Problematic	High	Low	Low	High
Iris	0,00001	0,016	Unsuccessful	High	Average	High	High
Retina	0,0001	0,4	Impossible	Average	High	Low	High
Vein Pattern	0,0008	0,01	Impossible	Average	Average	High	Average
Recognition by ECG	0,0005	0,01	Problematic	Average	Average	High	Average

The identification process can be divided into the following stages:

• collection of source data;
• signal preprocessing (filtering, etc.);
• extraction of characteristic features, their processing and template creation;
• comparison of the incoming template with a database of generated templates.

The most difficult problem in identification is the allocation of features that characterize the object. Several approaches based on the selection of parameters such as amplitudes, angles, vertical and horizontal components of the segments of the ECG signal are proposed [3,4].

To obtain an ECG, a training stand for the study of biomedical measurements KL-72001 was used. It is possible to connect 9 modules to this stand, one of which is an electrocardiogram module called KL-75001. This module serves to study the phenomenon of the occurrence of electrical potentials during heart contractions. The module uses 6 limb leads to record an electrocardiogram. Figure 2 shows a block diagram of an ECG measuring circuit with electrode clips, which are used to record very weak and time-varying potentials. Circuit limb choice contains a voltage follower circuit which matches the impedance between the electrode and the skin enhancing the measurement sensitivity. An isolation circuit is provided for the signal isolation and the power supply line using an optical method. The passband of the bandpass filter equals 0.1 - 100Hz and the gain of the amplifier is 10. Upon the signal passage through the notch filter with an average frequency of 50Hz, it is displayed on the oscilloscope screen.

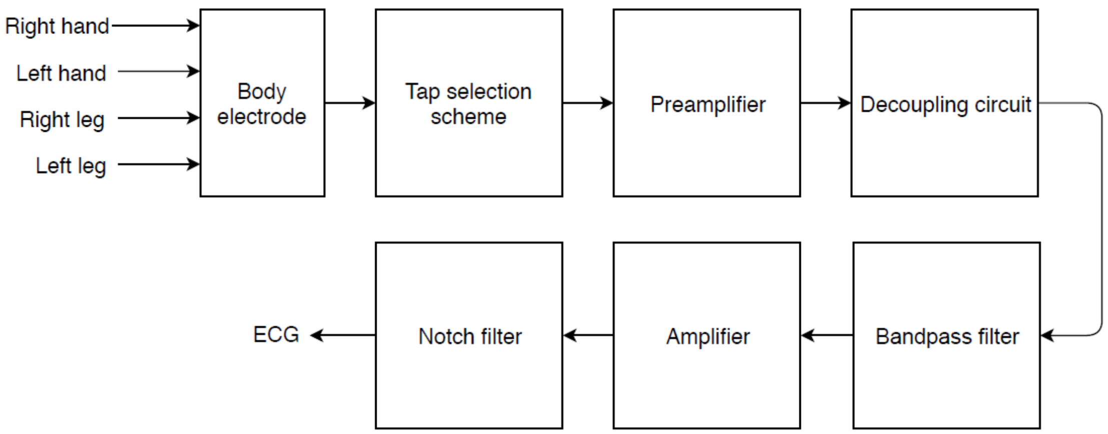

Fig.2. Block diagram of the ECG measuring circuit

The study used the first lead, by which it is clearly possible to identify the necessary protrusions and periods of electrical activity of the heart. To conduct an ECG analysis, the signal was recorded at the same time of the day under the same conditions in males aged 20-25.

A database (table 2) containing the values of the received voltage in each experiment was created. As a result of measuring bioelectric processes in the myocardium using an electrocardiograph and recording the signal in a digital form, the experiment was subject to a number of problems, such as low-frequency drift, noise, etc. [5, 6]. For analysis, the site with the minimal influence of interference is selected, the studied areas are chosen and the signal is filtered.

Table 2

Values of the received pulse waves

	Experiment No.									
	1	2	3	4	5	6	7	8	9	10
Amplitude, mV	-0,96	-0,64	-2,64	-2,08	-2,16	-2,88	-1,04	-0,8	-1,6	-2,08
	-0,72	-0,48	-2,48	-1,6	-2,16	-2,48	-0,96	-0,56	-1,36	-1,6
	-0,72	-0,24	-2,32	-1,36	-1,68	-1,92	-1,44	-0,24	-1,2	-1,36
	-0,4	-0,24	-1,92	-1,04	-1,44	-1,44	-2,08	-0,16	-0,8	-1,04
	-0,4	-0,16	-1,68	-0,88	-1,2	-1,12	-2,24	-0,16	-0,64	-0,88
	-0,32	-0,16	-1,36	-0,64	-1,04	-0,88	-2,16	-0,24	-0,48	-0,64
	-0,24	-0,24	-1,12	-0,48	-0,8	-0,48	-1,92	-0,4	-0,4	-0,48
	-0,4	-0,08	-1,04	-0,32	-0,88	-0,32	-1,76	-0,16	-0,32	-0,32
	-0,16	-0,24	-0,88	-0,16	-0,96	-0,16	-1,52	-0,4	-0,08	-0,16
	-0,08	-0,16	-0,8	0	-1,04	0,08	-1,2	-0,4	0	0
	0,48	-0,16	-0,72	0,16	-0,96	0,4	-0,8	-0,72	0,08	0,16
	0,16	-0,16	-0,56	0,16	-0,96	0,56	-0,24	-0,64	0,08	0,16
	0,56	-0,08	-0,4	0,32	-0,72	0,72	0,08	-0,88	0,16	0,32
	0,56	-0,16	-0,24	0,24	-0,8	0,8	-0,16	-0,56	-0,08	0,24
	0,56	-0,24	-0,08	0,4	-0,56	0,88	-0,08	-0,16	-0,08	0,4
	0,56	-0,16	0	0,4	-0,48	0,88	0	-0,72	-0,08	0,4
	0,72	-0,16	0,16	0,48	-0,32	0,8	-0,4	-1,04	0	0,48
	1,04	0	0,32	0,8	-0,16	0,8	3,52	-1,6	0,32	0,8
	0,4	0	0,32	0,88	0	0,56	5,76	-1,68	0	0,88
	0,08	0,08	0,96	0,48	0,08	0,48	-1,2	-1,92	-0,64	0,48

When constructing the selected areas Fig.3 was obtained, which shows ECG measurements over ten days of the study.

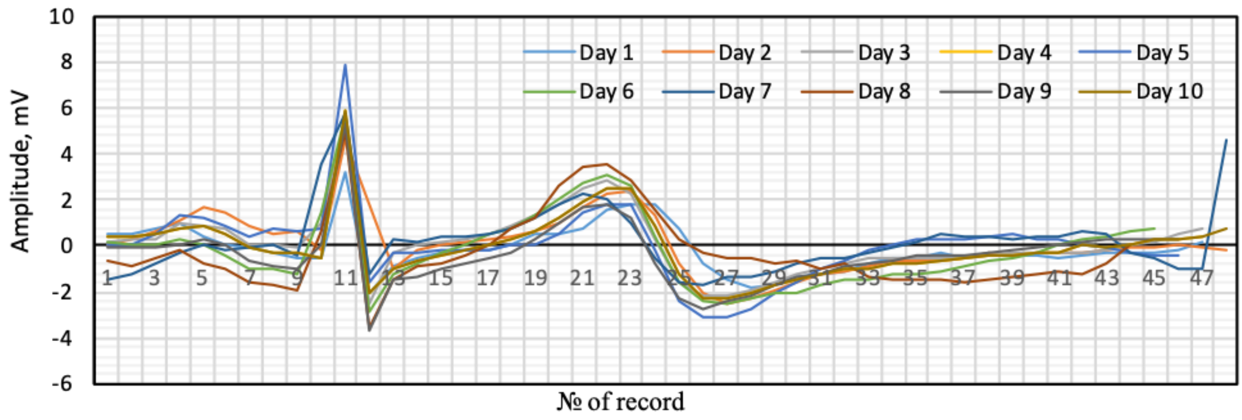

Fig.3. Graph of reference ECG curves for each experiment

Having selected the studied ECG sections, it is necessary to bring it to a form acceptable for analysis by digital filtering of the signal. Since the characteristic features of the electrocardiogram found in the identifiable may not be detected due to noise, several filtering methods must be used. For primary filtering Z-scaling of data (Table 3) is used, which is based on the mean and standard deviation: dividing the difference between the variable and the mean by the standard deviation [7].

Table 3

Z-Scaling Results

Report No	Voltage without Z-scaling, mV	Voltage with Z-scaling, mV	Report No	Voltage without Z-scaling, mV	Voltage with Z-scaling, mV
1	-2,08	-1,490960982	11	0,16	0,089178975
2	-1,6	-1,152359563	12	0,16	0,089178975
3	-1,36	-0,983058853	13	0,32	0,202046114
4	-1,04	-0,757324574	14	0,24	0,145612545
5	-0,88	-0,644457434	15	0,4	0,258479684
6	-0,64	-0,475156724	16	0,4	0,258479684
7	-0,48	-0,362289584	17	0,48	0,314913254
8	-0,32	-0,249422445	18	0,8	0,540647534
9	-0,16	-0,136555305	19	0,88	0,597081104
10	0	-0,023688165	20	0,48	0,314913254

Based on the graph (Fig. 4), we see that the amplitude values were normalized along the axis of the reports.

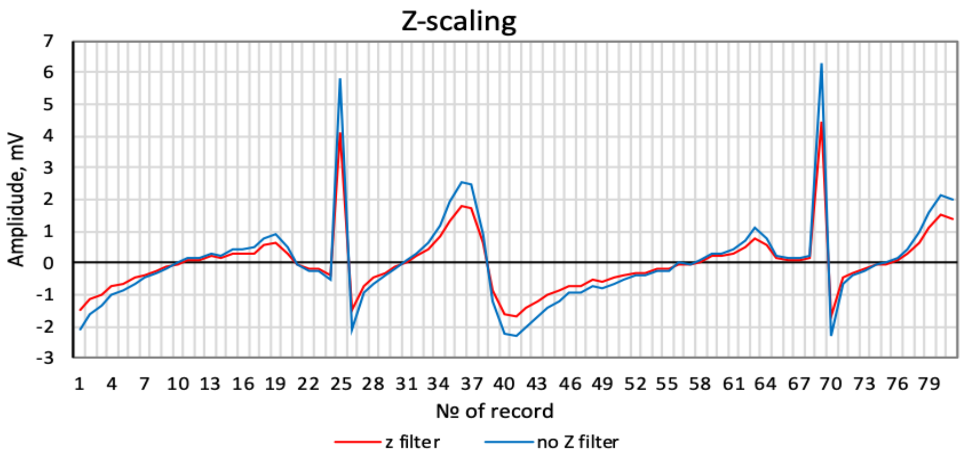

Fig.4. Z-scaling

After normalization the signal from noise can be filtered. All the noise contained in the electrocardiogram can be divided into three groups [8, 9]:

- Low-frequency noise (less than 1 Hz): fluctuation of the baseline caused by breathing, sweating, movement of the subject.
- Influence of the power frequency (50Hz): poor grounding of the electrocardiograph.
- High-frequency noise: the noise of a single heartbeat.

In order to remove such noise, the Butterworth highpass filter is used. The advantage of this filter is the smoothest frequency response at the passband frequencies and its decrease to almost zero at the suppression band frequencies. The Butterworth filter is the only filter retaining the shape of the frequency response for higher orders [10]. The results of applying the filter are shown in Fig. 5. As can be seen from the frequency response, all interference below a frequency of 100 Hz was partially not taken for further analysis

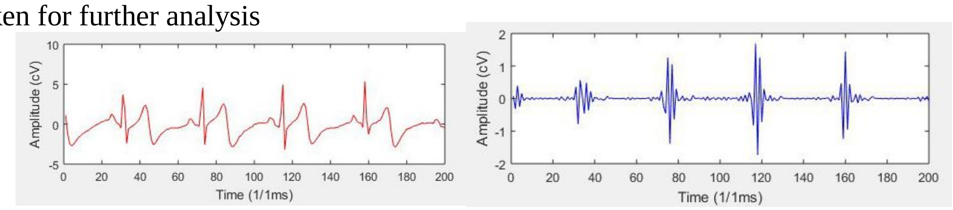

Fig.5. Using the HPF Butterworth

As the basis of the analysis, 30 parameters characterizing the waveform were taken. To reduce the number of parameters and highlight the most individual characteristics, a correlation analysis was used. A combination was obtained consisting of 8 variables describing one ECG pulse [11].

For identification, the method of formal independent modeling of class analogies was applied. This method allows to work with a large number of parameters by classifying spectroscopic data. A graphical representation of the processing circuit of the electrical signal of the heart for biometric identification is shown in Fig. 6.

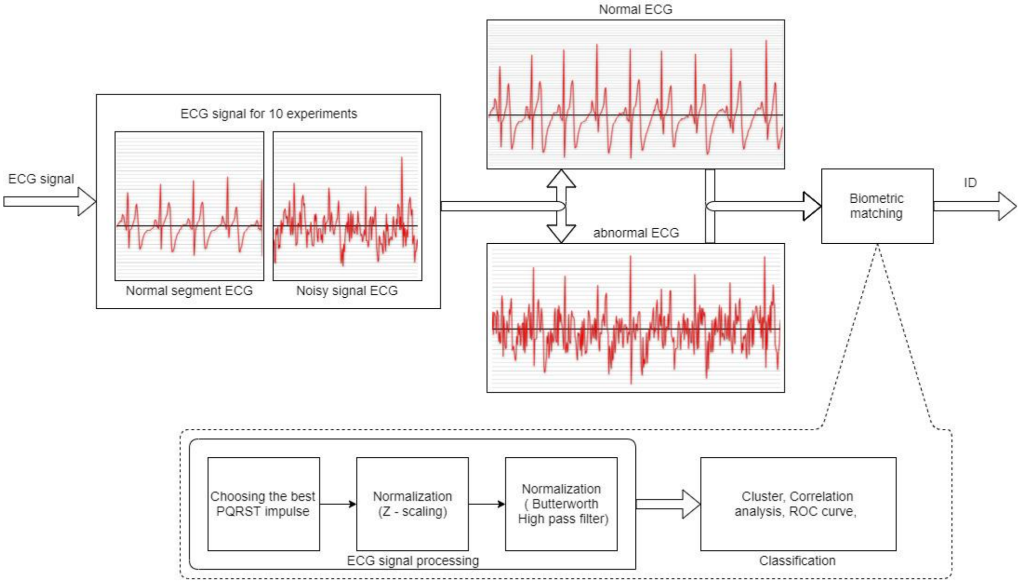

Fig. 6. Block diagram of signal processing

The first step is the principal component method, which is a method of reducing dimensionality or compressing data. As a result of the transition from a large number of variables to a new representation with a significantly lower dimension without loss of data describing the selection. An insignificant part of the data was defined as noise and eliminated. The found main components give an idea of the hidden variables that control the data device.

After constructing the ECG indicators of the main components in space, it is possible to calculate the distance between classes, as well as the distance from each class to a new object. A classification rule is defined in this space and the opportunity arises for identification.

Conclusions: Currently the possibilities of biometric identification of a person by ECG have not been sufficiently studied, however, these studies continue to be actively conducted. The main task is to study the possibility of highlighting the individual characteristics of the electrical activity of the human heart. Feature extraction usually consists of forming a template of relevant components, where some features are discarded, and only those, the statistical analysis method of which, showed the greatest increase in variance remain. This work also shows the high potential of using ECG for authentication with low-cost sensors, which allows developers to integrate them into automated medical systems to minimize errors in diagnostics, laboratory studies and to eliminate data falsification.

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ПІДВИЩЕННЯ ДОСТОВІРНОСТІ АНАЛІЗУ ЕЛЕКТРОКАРДІОГРАМИ ДЛЯ БІОМЕТРИЧНОЇ ІДЕНТИФІКАЦІЇ ОСОБИСТОСТІ

В останні роки спостерігається необхідність у використанні біометричної аутентифікації, яка за допомогою біологічних характеристик людини підтверджує її особу. Дані системи мають високий рівень захисту, так як оцінюють фізичні параметри і характеристики конкретної особистості. У роботі розглядалася біометрична схема, заснована на електричної активності людського серця у формі сигналів електрокардіограми (ЕКГ). Було виконано дослідження за допомогою стенду для медичних вимірів KL-720 протягом деякого часу, у пацієнтів певної вікової групи з одними і тими ж початковими умовами реєструвалася ЕКГ. В результаті отриманий сигнал електричної активності серця мав ряд артефактів і шумів. Завданням даної роботи було провести фільтрацію знятого сигналу для подальшого використання біометричними системами ідентифікації особистості.

Ключові слова: *електрокардіограма, біометрична ідентифікація, аутентифікація, параметри ЕКГ, високочастотний шум, низькочастотний шум, Z-масштабування, ФВЧ Баттерворда.*

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ПОВЫШЕНИЕ ДОСТОВЕРНОСТИ АНАЛИЗА ЭЛЕКТРОКАРДИОГРАММЫ ДЛЯ БИОМЕТРИЧЕСКОЙ ИДЕНТИФИКАЦИЯ ЛИЧНОСТИ

В последние годы наблюдается необходимость в использовании биометрической аутентификации, которая с помощью биологических характеристик человека подтверждает его личность. Данные системы имеют высокий уровень защиты, так как оценивают физические параметры и характеристики конкретной личности. В работе рассматривалась биометрическая схема, основанная на электрической активности человеческого сердца в форме сигналов электрокардиограммы (ЭКГ). Было выполнено исследование с помощью стенда для медицинских измерений KL-720 на протяжение некоторого времени, у пациентов определенной возрастной группы с одними и теми же начальными условиями регистрировалась ЭКГ. В результате полученный сигнал электрической активности сердца имел ряд артефактов и шумов. Задачей данной работы было провести фильтрацию снятого сигнала для дальнейшего использования биометрическими системами идентификации личности.

Ключевые слова: *электрокардиограмма, биометрическая идентификация,* аутентификация, *параметры ЭКГ, высокочастотный шум, низкочастотный шум, Z-масштабирование, ФВЧ Баттерворда*.