

The Method for Identification Complex Signals using the Example of Preliminary Diagnosis of a Myocardial Infarction

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Abstract— The possibility of a theory tools application of signals identification measurements for the preliminary diagnosis of a human's large-focal myocardial infarction is described. The analysis of the electrocardiological signals is used for this purpose. In particular, the dependence of a cardiovascular system condition on the offered integrated interaction factors is established. The size of the integrated interaction factor is determined allowing predicting the existence of separate groups of a myocardial infarction. The possibility of this technique application for a preliminary diagnostics of a human's cardiovascular system condition is offered.

Keywords—Algorithms, electrocardiographic signal, identification, myocardial infarction

I. INTRODUCTION

The human's cardiovascular system (CVS) pathology takes the leading positions on the growth rates, the level of prevalence, the disability degree and mortality in a modern society [1]. Wherein, the predominating position is held by a myocardial infarction. Its share makes up 13% among the other diseases of CVS. This fact demands searching of the new effective methods of the automated assessment of CVS condition capable to carry out an information support of the doctor's diagnostic decisions in the conditions of the increasing volume of physiological data, and in some cases to make preliminary automatic diagnosis of heart attacks [2].

It is obvious that as a basis of the automated CVS researches the method which is the most approved in clinical conditions, possessing the greatest informational content, available and inexpensive in use has to act. Such method today is the analysis of the electrocardiogram (ECG) representing

the projections record of the volume electric processes happening in heart in the form of the electrocardiographic signals observed on a body surface. The electrocardiogram carries information both on the current CVS condition and on the pathological changes in the heart [3].

By the most widespread ECG analysis method is deterministic [4]. The deterministic description of an electrocardiogram formalizing a cardiologist's tactics and modeling his activity is the basis for the algorithmic providing of this method. A cardiologist uses the structural recognition methods in the analysis of an electrocardiogram, allocating in this case the algebraic and logical signs of a signal structure. Consequently, the aprioristic description of classes contains both algebraic criteria and the criteria reflecting the interrelation (relations) of the separate signs. Depending on the comparison results of the received decision with some range established in advance, both the next electrocardiogram sign is measured, or the further electrocardiogram analysis stops and the set of the consistent conclusions on an electrocardiogram is formed [5].

The other conventional method of the analysis is the method of the spectral analysis [4]. The method essence consists in the use of the electrocardiogram spectral characteristics in the function of its generalized diagnostic signs. Despite a number of advantages, a frequency method didn't find the broad application at the traditional researches and the electrocardiogram analysis, in a type of difficulties connected with identification of the morphological elements on the frequency ranges. However the development and the wide use of the Holter systems showed the advantages of the

frequency methods application in the analysis of electrocardiograms long records [6].

The following method of the automated ECG analysis is based on the calculation of the correlation coefficient between the found electrocardiogram morphological element [7] and its sample [8].

The group of methods of intellectual information processing unites the methods of training and functioning of expert systems [9] and the methods of neurocomputer technologies [10].

As a result, the choice of a certain method of the ECG analysis has to be based, proceeding from a condition of its rationality and efficiency.

It is known that an electrocardiogram signal is quasiperiodic and non-stationary. It possesses the high degree of a variability depending on a large number of factors. The electrocardiogram signal is characterized by small amplitude (to mV units) and is the subject to hindrances influence of various natures. They include: power-supply noise; electromyographic hindrance; the base line drift owing to breath; contact noise of electrodes; the own noise of electronic devices, etc.

In this regard, ECG recognition for the purpose of a preliminary diagnosis of a myocardial infarction requires the creation of the highly effective intellectual systems capable to make the right decisions in the conditions of the obtained data specificity. Such systems giving the unambiguous solution of the specified recognition problem, at a large number which are already used and developed don't exist today.

In this article the approach to the problem solution of the automated electrocardiogram recognition on the regarding existence of the certain groups of a myocardial infarction by means of the theory facilities of signals identification measurements (TIMS) is offered [11].

II. BASE FORMATION OF THE ELECTROCARDIOGRAMS RECORDS

On problem solving the automated ECG recognition based on the TIMS (Theory of identification measurements of signals) the necessity is arose for the developed base formation of the analyzed records meeting the following requirements:

- the set of the studied records has to reflect the variety of signals forms with the realness high degree;
- seldom observed signals have to be a part of a records set, but possessing the clinical importance;
- signals which were a part of a set have to be annotated by the qualified specialists in the field of an electrocardiography.

The electrocardiograms records base of PhysioNet organization conforms the best to such requirements [12]. Among the ECG records bases of "PhysioNet" in the work PTB was used: The database of the National institute of metrology of Germany containing an electrocardiogram in norm and at pathologies (Physikalisch-Technische Bundesanstalt (PTB), the National Metrology Institute of Germany). Besides, in the work the ECG signals records from the data obtained from the local medical institutions with the

summaries of experts, and also, in some cases, by an electrocardiogram synthesis of the demanded form were used.

As a result the created records base contains the digitized electrocardiograms registered at least from 12 leads: three of them are standard, three are strengthened and six are chest.

In this work the authors used the data from 12 leads as this number of electrocardiographic leads gained the greatest distribution in a clinical electrocardiography. Electrocardiographic deviations reflect the total electromotive force of all heart in each of these leads, i.e. are the result of the simultaneous impact on this lead of the changing electric potential in the left and right departments of a heart, in anterior and posterior wall ventricles, in a heart top and base and etc.

The following designations of each of the leads are used in the work.

1. Three bipolar leads from extremities i, ii, iii;
2. Three unipolar leads from extremities avr, avl, avf;
3. Six chest leads v1, v2, v3, v4, v5, v6.

III ELEMENTS OF THE THEORY OF IDENTIFICATION MEASUREMENTS

The Theory of Identification Measurements of Signals (TIMS) is a complex of intellectual technologies (methods and computer facilities) of recognition and digital signals processing, the use of the separate achievements of which allows to solve positively the applied problems including in the field of CVS diagnostics on an electrocardiogram. The severalty connected with the problems solution of technical diagnostics is reflected in publications [13].

The content of TIMS are measurements of a form – distribution of transient values and variability – distribution of signal time intervals and its characteristics with the processing of identification parameters in the structure of the global standards by means of the identification scale (figure 1) consisting of the identification parameters testers (IdP-testers), the database (DB) and the logical analyzer.

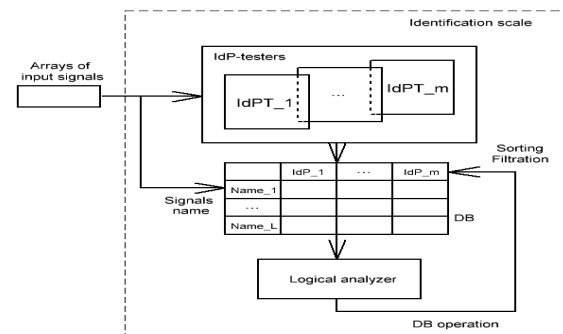


Fig. 1. Block diagram of an identification scale

IdP-testers transform arrays of input signals and characteristics to IdP numbers (identification parameters) which properties submit to the principles of a large-scale invariance, the equivalence and the coordinated orderliness. The built-in DB contains the values of identification parameters and the sorted names of a form and standards

variability. As the standards it can be signals of certain conditions of an object or signals with the well-known laws of transient value distributions. An intellectual power of a scale, an inherent resolution of hierarchical classification depends on the quantity of the used standards.

LA performs the delivery of the expert estimates (quantitative and qualitative) or recommendations about the results of identification measurements of a research signal and its characteristics, an application of methods and algorithms of sorting and a standard filtration, the comparison of the signals identification parameters with the reference values.

The feature of an identification scale is the possibility of measurement of different signal characteristics and its increments: temporary, spectral, probabilistic, correlated, wavelet and, above all, linguistic.

IV. TECHNIQUE AND INSTRUMENTS OF THE RESEARCH

A. Justification of the used research technique

Based on the principles of TIMS, the authors assumed the existence of opportunity by means of electrocardiogram identification measurements to receive the instrument of recognition of the pathological processes in CVS, peculiar myocardial infarctions. This assumption is based on that for a number of groups of heart attacks there are accurate electrocardiological signs of their emergence and development. Treat such signs:

- lack of R tooth in the leads located over the heart attack area;
- emergence of a pathological Q tooth in the leads located over the heart attack area;
- ST-segment elevation is higher than the isoline in the leads located over the heart attack area;
- discordant shift of the S-T segment is lower than the isoline in the leads opposite to heart attack area;
- negative T tooth in the leads located over the heart attack area.

Consecutive staging of the large-focal myocardial infarction is expressed in the essential natural changes of an electrocardiogram which sharply different from an electrocardiogram in the norm [3].

These signs will change the electrocardiogram form, and, therefore, according to authors, can be identified by the offered methods.

Being guided the mentioned above, the authors developed the research system which is considered further.

B. Research system

The research system which block diagram is submitted in figure 2 was developed for carrying out the researches on the electrocardiogram identification measurements on the structure basis of an identification scale. It consists of the signals reader (signals reader – SR), the identification logical analyzer of signals (identification analyzer signals – ISA), the comparator (comparator – C), databases of the signals reference (database signal standards – DBSS), tabular (table

classifier – TC) and hierarchical classifier (hierarchical classifier – HC), and also the interpreter.

By means of SR reading from a disk of ECG realization is made. The studied signals are analyzed by two channels: absolute (AMC) and relative (RMC) measurements. The ISA block measures some integrated identification parameters of signals from which in the further analysis two are used: IdP parameter and the degree of asymmetry (%Asym). These parameters serve for creation of two-dimensional tabular classification (TC block).

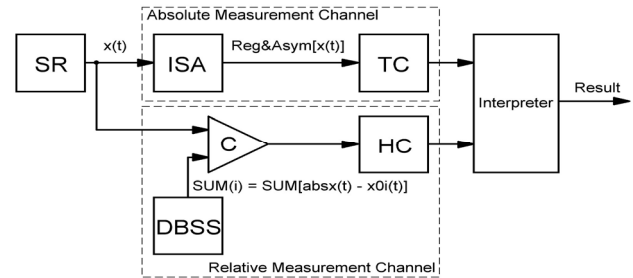


Fig. 2. Block diagram of the research system

Blocks of the comparator C and DBSS serve for the measurement of the input signals deviations from 16 reference signals system with the known distributions of transient values. To estimate the total value of deviations correctly, the studied and reference signals have to have identical number of counting (identical volumes of selections, N). The HC block makes sorting of reference signals according to deviations for each of the input signals.

The program code of the research system was realized in the NI LabVIEW environment of the graphic programming.. By sorting and a filtration of database records the linear and treelike classifications are based (in the environment MS EXCEL).

The system is the intelligent analyzer as contains the built-in database of standards which represent the sorted distributions of transient values of the casual signals and which are adjusted on a certain volume of the studied selection of an input signal.

At the conducted researches there were stored 16 standards in a database which number can be increased in the process of the requirements growth to a recognition quality.

The following designations of the transient values distribution of the used standards are accepted: 2mod – two-modal; asin – arcsin; bern-l – Bernoulli, left; bern-r – Bernoulli, right; binom – binomial; even – uniform; exp-l – exponential, left; exp-r – exponential, right; gamm – scale; gaus – normal; kosch – Cauchy; lapl – bilateral exponential; pois – Poisson; rele – the Rayleigh; simp – triangular; trap – trapezoidal distributions [13].

The research system operates with the electrocardiograms records meeting the following conditions.

- the electrocardiogram is received synchronously in 12 standard channels with a frequency of 1000 Hz sampling, word length of a-d converter of 16 bits, coefficient of strengthening 2000.

• the electrocardiogram signal is exposed to a preliminary filtration for the elimination of the high-frequency artifacts and the base line shift, and was also aligned.

C. TIMS' application for the problem solution of the myocardial infarction automated diagnosis.

Based on the primary opportunities of the TIMS instruments, it was developed and investigated by the authors the following techniques of the automated analysis and recognition of a myocardial infarction on an electrocardiogram.

1) *Step 1.* For each studied electrocardiogram of the corresponding lead the general selection of transient values $\{x_i\}$ is formed and identification parameter is defined

$$Id_x = \left[\frac{\max\{x_i\} - \min\{x_i\}}{\sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{X})^2}} \right]^2 \quad (1)$$

where $\max\{x_i\}$ and $\min\{x_i\}$ – maximum and minimum value of selection;

$\bar{X}$ – an average value.

Further parameter $\%Asym_R$ is determined by the following dependence

$$\%Asym_R = \frac{Id_x - Id_R^E}{Id_x} 100\%, \quad (2)$$

where Id_R^E – identification parameter of a standard (E_R);

R – the serial number of a standard in an initial (unsorted) database.

2) *Step 2.* The received identification parameters $\%Asym_j$ are sorted by a deviation in the increasing order

$$Channel(K) = \left\{ \begin{array}{l} < E_1^K (\%Asym_j^{MIN}) > \\ \dots \\ < E_J^K (\%Asym_j) > \\ \dots \\ < E_{16}^K (\%Asym_j^{MAX}) > \end{array} \right\}, \quad (3)$$

where k – the number of leads (the measuring channel);

J – the serial number of a standard sorted row.

The name lists ordered on a deviation of ECG standards with the diagnosed myocardial infarction are presented in *table I* (the man, 51 years).

3) *Step 3.* Ordering on a deviation of the standards names, allows estimating a force interaction between the studied signals in the form of a symmetric matrix. For its creation the names of standards are compared in the identical positions in the ordered lists between all leads.

$$\begin{array}{l} < Channel(K) > \neq \& = < Channel(K+1) > = \\ \left\{ \begin{array}{l} < E_1^K (\%Asym_j^{MIN}) > \\ \dots \\ < E_J^K (\%Asym_j) > \\ \dots \\ < E_{16}^K (\%Asym_j^{MAX}) > \end{array} \right\} \neq \& = \left\{ \begin{array}{l} < E_1^{K+1} (\%Asym_j^{MIN}) > \\ \dots \\ < E_J^{K+1} (\%Asym_j) > \\ \dots \\ < E_{16}^{K+1} (\%Asym_j^{MAX}) > \end{array} \right\}, \end{array} \quad (4)$$

where $< E_j^K (\%Asym_j) >$ – a standard name (the linguistic characteristic).

Further the symmetric matrix coefficients are determined by relative number of coincidence of the standards names

$$C(Channel(K, K+1)) = \frac{\sum_{j=1}^{16} C_{j,K,K+1}}{16}, \quad (5)$$

where

$$C_{j,K,K+1} = \begin{cases} 1, & \text{while } < E_j^K (\%Asym_j) > = < E_j^{K+1} (\%Asym_j) > \\ 0, & \text{while } < E_j^K (\%Asym_j) > \neq < E_j^{K+1} (\%Asym_j) > \end{cases}$$

At the following stage the interaction factor as the sums values of the symmetric matrix coefficients are determined by each lead.

$$M(Channel(K)) = \sum_{k=1}^{12} C_K(Channel(K, K+1)) \quad (6)$$

The values of the interaction factor, in the form of a matrix, for the ordered list of names of ECG standards for a signal from the *table I* are presented in the *table II*.

In the *table II* in the lower line the sums values of the interaction factor on each lead are presented at which summation the value of the integrated ECG interaction factor for 12 leads is turned out.

$$M = M(avf) + M(avl) + M(avr) + M(iii) + M(ii) + M(i) + M(v6) + M(v5) + M(v4) + M(v3) + M(v2) + M(v1). \quad (7)$$

Then for the analyzed electrocardiogram signal the integrated interaction factor is equal to $M = 45,625$.

By similar way with application of expressions (1) – (6) the values of the integrated coefficients M for 40 ECG signals in norm were determined and at the diagnosed myocardial infarction from the created database records which are selected in a random way. V .

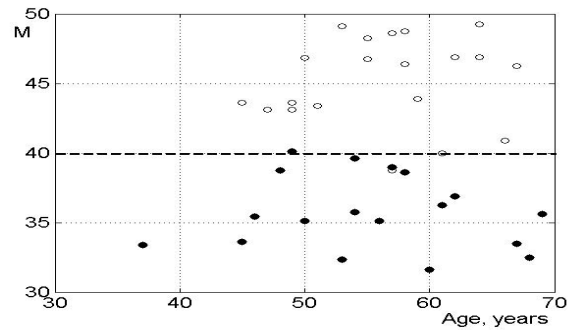


Fig. 3. Distribution of M integrated indicator depending on age
• – healthy patients;
○ – patients with the diagnosis a myocardial infarction

RESULTS

In figure 3 the schedule of M integrated indicator distribution for the studied electrocardiograms records depending on the patient's age is submitted.

The age parameter was chosen for the accounting of influence possibility on the research results of the age-related changes of signals form.

The analysis of the control selection of 40 electrocardiograms records by the offered TIMS methods allows identifying a data clustering rather accurately in two areas. For the designation of these groups in figure 3 markers of black and white color are used.

VII. DISCUSSIONS

The analysis of the experimental data of figure 3 allows drawing a number of important conclusions.

The section limit of clusters is defined by means of a linear clustering of data by the division of masses centers. However because of an interpenetration of the clustering data the authors define the existence of some transitional area and

allow the linear decisive rule in the form of a trend straight line $y = 40$. In that case it is possible to claim that the probability of a myocardial infarction existence accepts the essential value at the hit of the integrated coefficient in the range $M > 40$.

In the analysis of the female patients' records only from the analyzed selection the clustering of an integrated coefficient is traced accurately with the border at $M = 40$. The records with the value $40 < M < 50$ unambiguously belong to the group with the diagnosis a myocardial infarction. The interpreted data don't contain the emissions outside clusters.

Analyzing also the available graphic data it is possible to note that the size of an integrated indicator poorly correlates or doesn't correlate with the patients' age.

According to it, on the basis of the obtained experimental data it is established that the offered technique provides the probability of an identification of a large-focal infarction in 90% of cases. For some groups of data this indicator changes in the big party.

TABLE I
THE ECG STANDARDS NAME LISTS ORDERED ON A DEVIATION WITH THE DIAGNOSED MYOCARDIAL INFARCTION

<Channel (K)>												
K	1	2	3	4	5	6	7	8	9	10	11	12
J	avf	avl	avr	iii	ii	i	v6	v5	v4	v3	v2	v1
1	rele	lapl	lapl	rele	rele	rele	rele	rele	gaus	lapl	exp-r	kosh
2	gaus	gaus	simp	gaus	gaus	gaus	gaus	kosh	lapl	gaus	lapl	exp-r
3	simp	simp	gaus	simp	simp	simp	simp	gaus	kosh	simp	even	simp
4	trap	trap	trap	lapl	trap	lapl	lapl	lapl	simp	kosh	gaus	trap
5	lapl	even	even	trap	lapl	trap	trap	simp	rele	trap	simp	gaus
6	even	rele	exp-r	gamm	gamm	gamm	even	trap	trap	even	trap	lapl
7	asin	binom	asin	even	even	pois	gamm	even	even	rele	asin	even
8	binom	asin	binom	pois	kosh	even	kosh	gamm	binom	binom	binom	asin
9	gamm	kosh	kosh	asin	pois	exp-l	pois	pois	gamm	asin	bern-r	binom
10	pois	gamm	rele	exp-l	asin	asin	binom	binom	asin	gamm	2mod	bern-r
11	exp-l	pois	bern-r	binom	exp-l	binom	asin	asin	pois	pois	rele	rele
12	kosh	exp-l	2mod	kosh	binom	kosh	exp-l	exp-l	exp-l	exp-l	bern-l	2mod
13	bern-l	exp-r	gamm	bern-l	bern-l	bern-l	bern-l	bern-l	bern-l	exp-r	gamm	bern-l
14	2mod	2mod	bern-l	2mod	2mod	2mod	2mod	2mod	2mod	2mod	pois	gamm
15	bern-r	bern-l	pois	bern-r	bern-r	bern-r	bern-r	bern-r	bern-r	bern-l	exp-l	pois
16	exp-r	bern-r	exp-l	exp-r	exp-r	exp-r	exp-r	exp-r	exp-r	bern-r	kosh	exp-l

TABLE III
MATRIX OF THE INTERACTION FACTOR BETWEEN THE STUDIED ELECTROCARDIOGRAMS WITH THE DIAGNOSED MYOCARDIAL INFARCTION

Channel (K)												
K	1	2	3	4	5	6	7	8	9	10	11	12
Z	avf	avl	avr	iii	ii	i	v6	v5	v4	v3	v2	v1
avf	1	0,25	0,1875	0,5	0,625	0,5	0,5	0,3125	0,375	0,375	0,125	0,1875
avl	0,25	1	0,25	0,1875	0,25	0,1875	0,25	0,125	0,1875	0,625	0	0,1875
avr	0,1875	0,25	1	0	0,0625	0	0	0,0625	0,0625	0,125	0,1875	0,25
iii	0,5	0,1875	0	1	0,5625	0,75	0,5625	0,375	0,3125	0,3125	0	0,1875
ii	0,625	0,25	0,0625	0,5625	1	0,5625	0,5625	0,4375	0,375	0,1875	0	0,25
i	0,5	0,1875	0	0,75	0,5625	1	0,5625	0,375	0,3125	0,25	0	0,125
v6	0,5	0,25	0	0,5625	0,5625	0,5625	1	0,625	0,3125	0,375	0	0,125
v5	0,3125	0,125	0,0625	0,375	0,4375	0,375	0,625	1	0,4375	0,125	0,125	0,125
v4	0,375	0,1875	0,0625	0,3125	0,375	0,3125	0,3125	0,4375	1	0,25	0,1875	0,125
v3	0,375	0,625	0,125	0,3125	0,1875	0,25	0,375	0,125	0,25	1	0,0625	0,0625
v2	0,125	0	0,1875	0	0	0	0	0,125	0,1875	0,0625	1	0,0625
v1	0,1875	0,1875	0,25	0,1875	0,25	0,125	0,125	0,125	0,125	0,0625	0,0625	1
M	4,9375	3,5	1,9375	4,75	4,875	4,625	4,75	4,125	3,9375	3,75	1,75	2,6875

Doing attempt of the comparison of the research results to the data of the other modern writers working on the objective solution by the alternative methods it is possible to state a little big efficiency of the offered technique in the comparison with the works [15] and [16] which show a successful detecting of a heart attack in 78,1 and 88% of cases respectively.

At the same time, the offered technique isn't capable to reveal the localization of a heart attack as it operates with an integrated interaction factor. Also the applicability of technique is limited to those types of myocardial infarctions which obviously aren't detected on an electrocardiogram. It should be noted that the analysis results have preliminary character and in the long term can be only one of the signs for the statement of the final diagnosis by the cardiologist.

On the basis of the conducted researches, the authors predict that at the accumulation of the electrocardiograms identification parameters enough in a database there will be more opportunities for searching of the hidden regularities in the structure of the classification symptoms of the diagnosed diseases.

VIII. CONCLUSION

During the search for the problem solution of the automated diagnosis of a human's myocardial infarction in the electrocardiograms records the research system allowing to work with the experimental data in the NI LabVIEW environment of programming, to carry out their preliminary processing according to the requirements of TIMS is realized by the authors.

The analysis of the received results during the conducted researches testifies to the following. The electrocardiograms received with use of the research system are quasiperiodic and non-stationary signals, and their identification measurements show a wide spacing of the identification parameters even within the existence of a myocardial infarction or within norm. The application of TIMS gives the chance to systematize the signals, which allowed offering the techniques of identification measurements and the analysis of the electrocardiograms forms and algorithms of the preliminary diagnostics of CVS state.

The substance of the offered technique is the determination of CVS state dependence from the integrated coefficients for 12 electrocardiogram leads defined with the application of TIMS and ordered on the lists rejection of the standards names.

Consequently, in the conditions of a technical equipment variety applied in the field of cardiological research and also at the increasing volume of a diagnostic information, for the preliminary diagnosis of the myocardial infarctions it is offered to realize the electrocardiographs in the form of the expert systems with the developed database of codes, clusters and ECG integrated interaction factors received on the basis of identification measurements.

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