GEOMETRICAL MODELLING OF ELECTROCARDIOGRAMS FOR THE PURPOSE OF DIAGNOSTICS OF HEART DISEASES

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***Summary.* The review of methods of geometrical treatment of cardiograms by means of phase portraits which proves is provided that application of a phase portrait of an electrocardiogram gives the chance to estimate adequately a form of separate fragments of an electrocardiogram and to reveal in it such deviations which are heavy for defining in the traditional analysis of an electrocardiogram.**

***Keywords:* electrocardiogram (ECG), modeling ECG, ECG examination phase portrait.**

Formulation of the problem. One of the main problems that arises in the treatment of cardiovascular diseases, is to establish an accurate diagnosis of the disease, and subsequently the appointment of proper treatment. Electrocardiogram (*ECG*) is still quite important diagnostic tool in cardiology. Therefore, actual research work will [1,2] aimed at automating the decryption electrocardiograms adequacy for the purpose of diagnosis of the disease. This will provide timely care to patients, including surgery. After all, according to official figures in Ukraine cardiovascular disease affects about 25 million. People, or more than half the population. The mortality rate from diseases of the cardiovascular system in Ukraine is higher than in most other countries. The growth of mass illness that lasts (especially among young people), making heart disease a major health and social problems, and cardiology - one of the most important health [1,2].

The first successful open heart surgery was performed in Ukraine in 1958, a heart surgeon M. Amosov using cardiopulmonary bypass machine of his own design [3,4]. Later he became the world's first heart surgeon who began to actively develop Biocybernetics, apply new approaches to modeling complex systems of the human body, in practice approaches to justify their use. For the first time in the world he created and implemented in practice antithrombotic prosthetic heart valves. Along with M. Amosov cardiology in Ukraine and abroad Ukrainian leaders have developed such medicine as M.D. Strazhesko, A.A. Shalimov, today I.M. Yemets and others. As a result, domestic technologies were launched operations coronary bypass surgery on a beating heart (without cardiopulmonary bypass), thus at times exceed the quality indicators compared with overseas. Among the positive trends of recent years can note the drop in mortality from myocardial infarction, which now stands at 13%. Achieving Ukrainian cardiologists go at the achievements of European scientists.

Analysis of recent research. The first who introduced electrocardiography in medical practice, was a physiologist W. Einthoven, who in 1893 created the first electrocardiograph and developed the first theory of the genesis of the *ECG*. This invention was preceded by research scientists IM Medical Academy, G. Lippmann, G. Kellikera, H. Muller et al. They were discovered and investigated the presence of electrical phenomena in the myocardium, namely, the imposition of nerve bone muscle to heart watching frogs rhythmic contractions of the muscles to the beat of the heart contractions. That was the way the doctors who gave information about heart. [4]

Electrocardiogram is a graphic representation of time passing electrical impulse conduction system in the heart. Typical *ECG* man has five positive and negative fluctuations - teeth corresponding cardiac cycle. They represent Latin letters from *P* to *T* (Fig. 1). The gaps between the teeth are called segments, a set of teeth and segment - interval. Three big teeth - *P, R, T* - tops turned up two small - *Q, S* - facing downward. [4]

Each graphic element reflects ECG medical condition certain parts of the heart. For example, *P* wave gives information about atrial being algebraic sum of the potentials that occur in the right and left atrium. The interval *PQ (R)* reflects the length of time of pulse propagation in the atria, *AV* node, bundle branch block and Purkinje fibers. *QRST* complex curves due to the spread (complex *QRS*) and fading (*RS-T* segment and tooth *T*) excitation in ventricular myocardium, as it is called ventricular complex. The excitement begins with a ventricular depolarization interventricular septum that leads to the *ECG* integral vector - face down tooth *Q*. prong *R* is the highest in the *ECG*. It defines the period of pulse propagation in ventricular myocardium. Prong *S* reflects the excitation wave propagation in basal parts of the interventricular septum right and left ventricles. *T* wave reflects the restoration of normal myocardial cell membrane potential, ie its repolarization. *TP* segment coincides with a period of rest the heart - diastole. This segment should take the level isoelectric lines in normal and pathology [4].

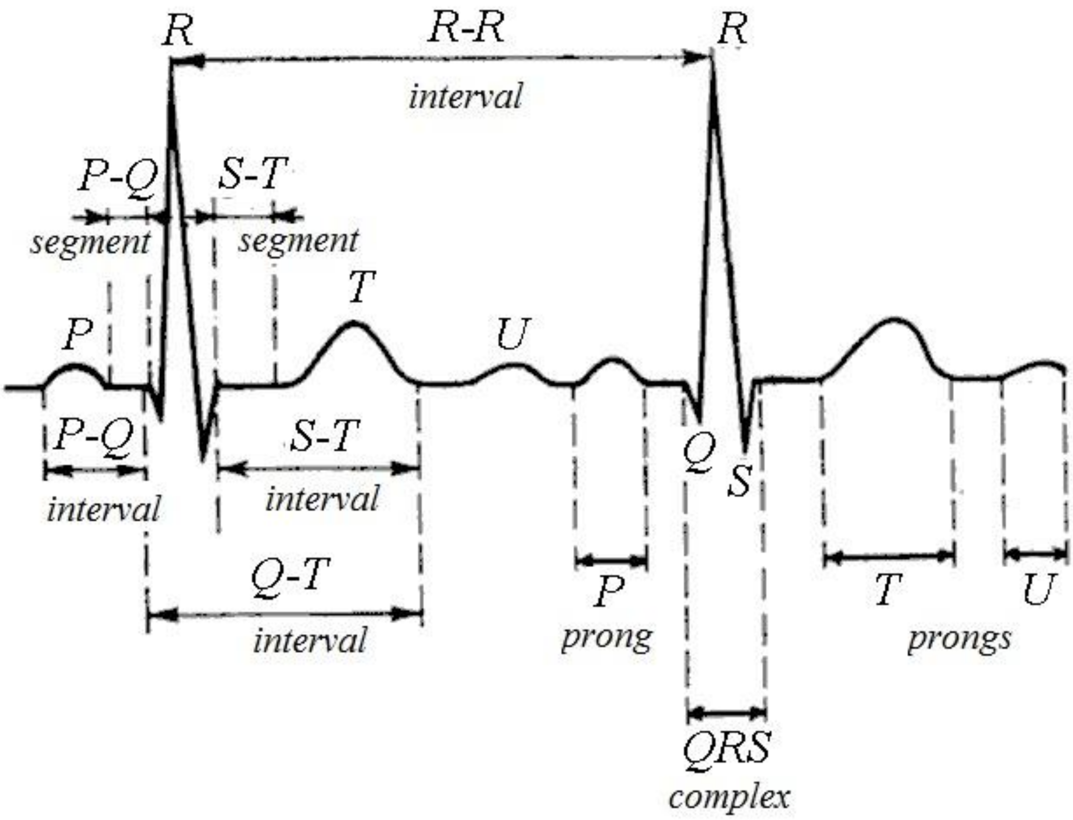


Fig. 1. Typical *ECG* person who is responsible
cardiac cycle.

Formulation of Article purposes. Run a review of methods of geometrical interpretation of electrocardiograms using phase portraits, and prove that the use of phase portrait *ECG* makes it possible to adequately assess the form of fragments *ECG* and discover there are deviations that are difficult to define in traditional *ECG* analysis.

Main part. Above were given graphic elements cardiogram healthy heart. But the human heart is able to respond to internal and external stimuli faced man, so his job pretty easy to break, which is manifested in the form of arrhythmias [1,2,4]. Arrhythmia - is any abnormal heart rhythm, characterized by a change in frequency, regularity and consistency heart rate as a result of violation of the fundamental functions of the heart: automatism, excitability and conductivity. Arrhythmia and its diagnosis using *ECG* - the two most important topics of interest to the cardiologist doctor and his patient. Cardiogram considered to be the most common way to diagnose arrhythmias. She is the "lifeline" that allows you to quickly gather the necessary information for the correct diagnosis. French writer Marie Sevynye assured that "the heart does not have wrinkles." But geometry *ECG* for most diseases can be distorted, creating not only the "wrinkles", but scars. In practical guide describes the *ECG* plenty of electrocardiographic signs of arrhythmia, such as blockades conduction system of the heart. Change *ECG* geometry can be traced in hypertrophy and left and right atrial myocardial infarction. Cardiogram appointed almost all people who have complaints or suspected malfunction of the heart, because it is one of those diagnostic methods, which allows the doctor to establish the correct diagnosis.

However, *ECG* examination often reflect the dynamics of the pathological process is not enough. In recent decades, based on advanced computer technologies, new methods of *ECG* analysis. Among them promising area is the improvement of diagnostic ECG analysis presented in phase coordinates [6]. This trend is developing in the works *PhD*, chief scientific officer L. Fainzilberg and his students [5.8] in the International scientific-educational center of information technologies and systems *NAS* of Ukraine.

To build phase portraits analog *ECG* graph which describes the function $y = y(t)$, should the plane choose Cartesian coordinate system in which, depending on the parameter t on the vertical axis delay value $y(t)$, and the horizontal - meaning the derivative of this function obtained, for example, by using differentiator (Fig. 2).

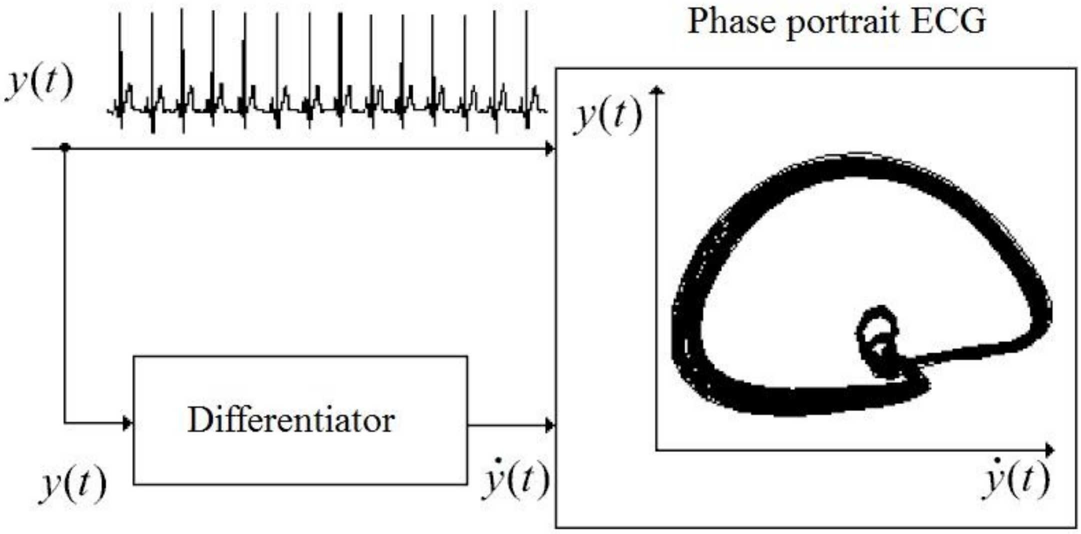
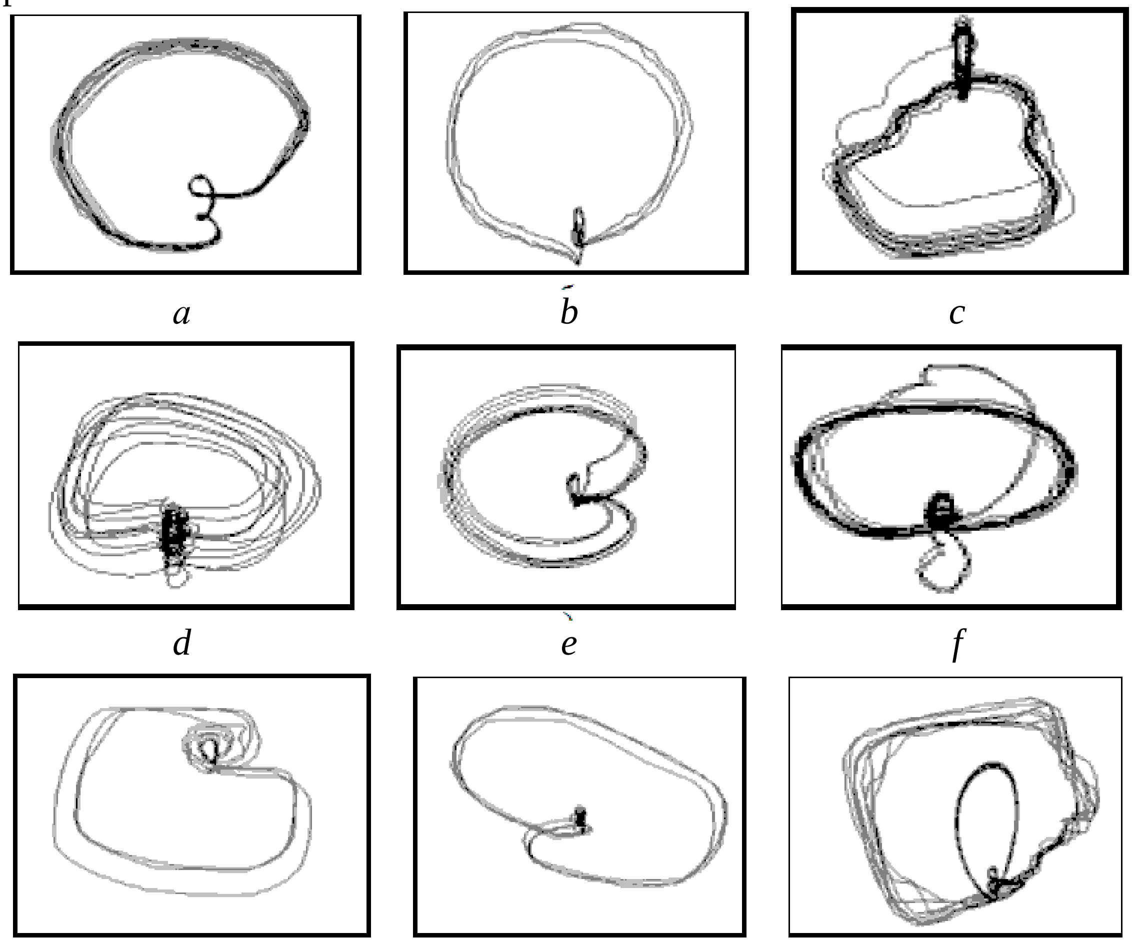


Fig. 2. Scheme of analog phase portrait ECG.

Selected plane $y(t) - \dot{y}(t)$ called phase coordinates on it - phase and phase trajectories set depicting changes in the state "vibrational" system - phase portrait.

ECG analysis phase in these coordinates enables to simultaneously evaluate both amplitude and speed performance of individual elements of *ECG* signal. This allows you to accurately assess the structure *ECG* and found it such deviations that can’t be detected by the traditional electrocardiogram analysis as a "tape". Experience in construction and analysis of phase portraits showed their ability for preliminary diagnosis of heart disease. The work L.Faynzilberh and T.Lebedushko [8] are examples of phase portraits (Fig. 3), geometric forms are essentially dependent on the patient.



a *b* *c* *d* *e* *f* *g* *h* *i*

Fig. 3. The phase portraits Gallery ECG.

Here are explanations of the ECG phase portraits in Fig. 3: *a* - man, 64 years old, diagnosed with "AV-block"; *b* - man, 69 years old, diagnosed with "a myocardium heart attack"; *c* - woman, 89 years old, diagnosed with «AV block and left bundle branch block"; *d* - woman, 84 years old, diagnosed with "paroxysmal atrial flutter, nodal rhythm»; *e* - man, 32 years old, diagnosed with "syndrome of Wolff-Parkinson-White"; *f*- woman, 51 years old, diagnosed with "pronounced beats"; *g* - woman, 61 years old, diagnosed with "heart failure"; *h* - man, 47 years old, comprehensive diagnosis of "mixed angina, myocardial infarction"; *i* - man, 41 years old, diagnosed with "myocarditis and hypertension."

Studies have shown [8] that the phase portraits *ECG* quite diverse, and their differences are more pronounced than differences "band" signals

$y(t)$, by which they were formed. Moreover, with the advent of diagnostically significant *ECG* abnormalities in the time domain at the appropriate phase plane portrait $y(t)-\dot{y}(t)$ there are characteristic changes (signs) that quite simply can be detected both visually and by computer algorithms. Represents interest also study the dynamics of change of phase portraits, including the stage of treatment when taking medications. In analyzing the *ECG* in phase space $y(t)-\dot{y}(t)$ it is possible to use the additional features that are almost imperceptible by visual analysis of *ECG* in the time domain and therefore often underestimated cardiologists [5-8].

But because nonperiodicity *ECG* as phase portrait of the plane $y(t)-\dot{y}(t)$ often will set phase curves (Fig. 4), which for ease of use necessary "to average".

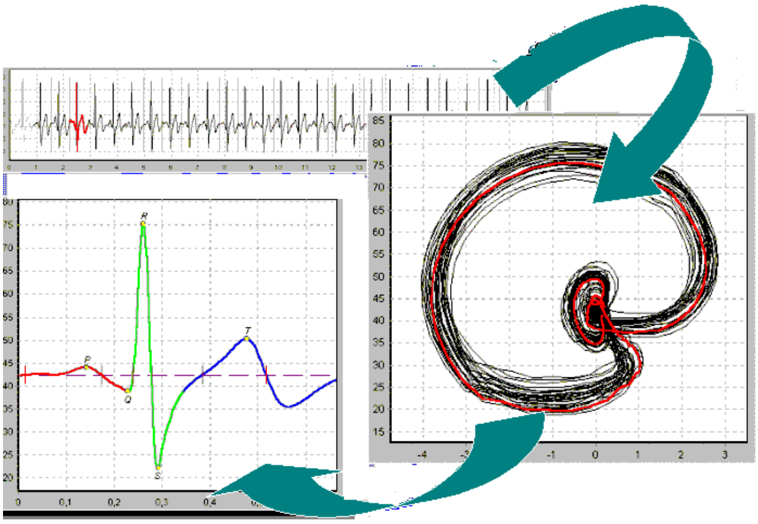


Fig. 4. Preparation of "average" phase
portrait of a combination of phase curves.

As shown in [8] after the formation of "average" phase portrait in question an opportunity to describe the oscillatory process using differential equations. After *ECG* display coordinates $y(t)-\dot{y}(t)$ is a graphic-analytical method of research of "vibrational" system, the status of which is described by differential equations

$$\dot{x}_1 = x_2; \tag{1}$$

$$\dot{x}_2 = F(x_1, x_2), \tag{2}$$

where $x_1 = y(t)$ - output coordinate system (i.e. amplitude *ECG* time t), $x_2 = \dot{y}(t)$ - its first derivative, and $F(x_1, x_2)$ - some nonlinear function.

Dividing the expression (2) to (1), we obtain an equation in which there is no time *t* explicitly:

$$\frac{dx_2}{dx_1} = \frac{F(x_1, x_2)}{x_2}\ . \qquad (3)$$

Solution equation (3) can be written as

$$x_2 = \Psi(x_1) \qquad (4)$$

or, considering signs $x_1 = y(t)$ i $x_2 = \dot{y}(t)$, as

$$\dot{y}(t) = \Psi(y(t)) \qquad (5)$$

phase and who will determine the trajectory of the plane $y(t) - \dot{y}(t)$.

On the basis of the dependency phase trajectories can be described as Attractors and build some dynamic systems [8-10].

Example. As a result of solving differential equations

$$x_1 = \dot{y}(t) + a\left(y(t) - \exp\left(b\sin(2\pi t) - y(t)\right)\right); \quad x_2 = \dot{x}_1(t) \qquad (6)$$

define function *y(t)*.

For this we use language operators maple:

```
x1:=diff(y(t),t)+a*(y(t)-exp(b*sin(2*Pi*t)-y(t))):
x2:=diff(x1,t);
sol:=dsolve({x2, y(0)=0, D(y)(0)=1},y(t),numeric,
                    output=listprocedure);
```

function defined *y(t)* and its derivative `yt:=subs(sol,y(t)) :`
`vt:=subs(sol,diff(y(t),t)) :`

Fig. 5 shows the relevant schedules and phase portrait.

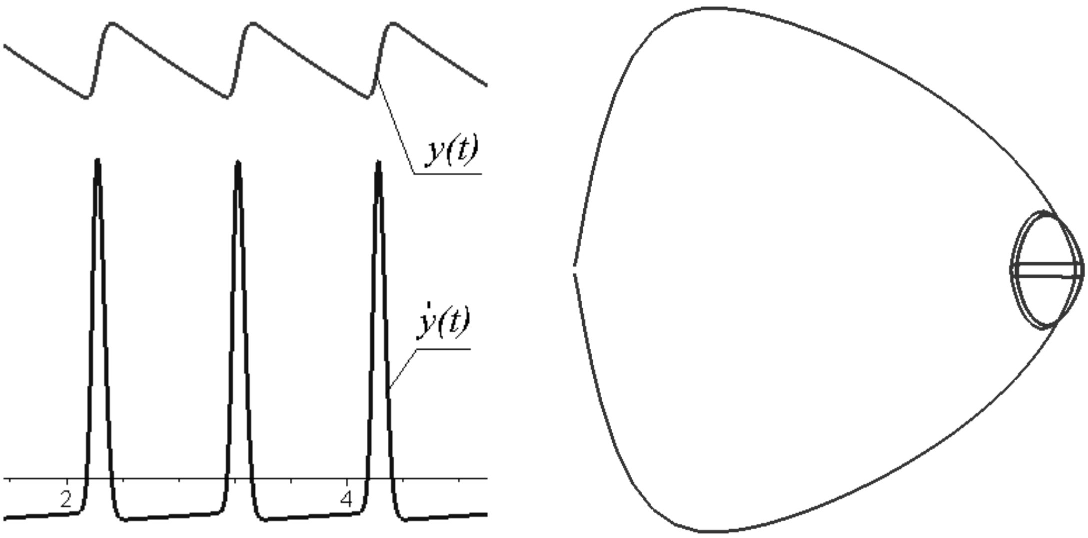


Fig. 5. The graph of *y(t)* and its derivative
and phase settings for portrait *a* = 0,25; *b* = 15.

Conclusions. Completed overview of studies [3-8] proves that the phase portrait ECG provides an estimate of individual fragments form the ECG and discover there are deviations that can’t be determined by traditional analysis of ECG as a "tape".

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