

Секція проблем моделювання процесів і систем

PECULIARITIES OF PROCESSING INFORMATION PARAMETERS OF COMPLEX OBJECTS WITH STOCHASTIC INFLUENCE

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The article proposes the use of the HRV signal attractor for the analysis of heart rate variability, which allowed a new understanding of heart rate changes in various physiological states, including in the presence of external factors. The use of the proposed approach provides additional prognostic information and complements the traditional analysis of heart rate variability, since it is the change in the dynamics of heart rate variability that has prognostic value regarding the progression of the impairment of the stability of the functional state of the operator.

Timely diagnosis and forecasting of health problems of airline operators has certain features compared to operators of other professions. Operator of aviation activities: flight crews, dispatchers, operators of ground services work in special conditions of influence of destabilizing factors in the process of performing professional duties [1]. Moreover, the influence of these factors is stochastic in nature and often does not lend itself to mathematical modeling [2]. Despite the meticulous selection during medical certification, the operator's body has a certain adaptation potential, the overload of which can lead homeostasis out of a state of functional equilibrium. Therefore, the search for technologies and methods for predicting the stability of the functioning of the operators' organism as a complex object that is subject to stochastic influence and determining their current adaptive reserves for the effective use of human resources is an urgent task. The use of the analysis of parameters of the cardiovascular system for the analysis of functional stability is related to its vulnerability to destabilizing factors.

Therefore, it is believed that the parameters of the cardiovascular system are the most informative from the point of view of assessing biological imbalance [2]. But the classical approach to the analysis of cardiac signals in the time and frequency domains revealed that the

formation of a cardiac signal has a more complex structure than can be described using classical approaches [2].

Therefore, today more and more additional methods are used to increase the reliability of cardiac signal processing, but the study of empirical data to establish the correlation between classical and new approaches in the analysis of cardiac rhythm signals is an urgent task. Heart rate variability (HRV) is one of the most promising indicators for determining the analysis of quantitative studies of indicators of the autonomic activity of the heart.

Today, various approaches are used to automate both the process of measuring and processing HRV, but the meaning and importance of many HRV indicators are more complex than it is commonly believed. Therefore, the study of nonlinear dynamics methods for evaluating complex cardiovascular rhythm processes will provide an opportunity to obtain additional information about the state of both the cardiovascular system itself and the stability of the functioning of the entire organism as a whole, and will provide more potential opportunities when making decisions about the state of operators and will allow, in addition to quantitative values of medical and biological parameters to obtain additional information about dynamic changes in the state of the system at different intervals of time.

Moreover, the time during which these empirical data were obtained also has an informational component. Most medical parameters (electrocardiograms, electroencephalograms, electromyograms, and others) represent both linear physiological processes and have a component that describes certain non-linear processes in the body as the body's reaction to external destabilizing influences. While the linear component of the system is described with a certain reliability by classical methods of intellectual analysis, the nonlinear processes in the body are not sufficiently described and researched. The nonlinear phenomenon is one of the reasons for the variability of medical and biological parameters, the variability of the heart rate in particular [3].

When studying the complex dynamics of parameters of the cardiovascular system, the classical approach based on analytical calculations of individual trajectories, for example based on differential equations, does not work. For this reason, there is a need to study the functional stability of the organism based on the study of the role of invariant varieties of the transformation of information parameters of the cardiovascular system, analysis of the geometric structure of the trajectories of time series formed on the basis of the cardio signal.

Although such an approach does not make it possible to present the solution in an explicit form, it allows to qualitatively describe many important features of the organism as a dynamic system. Given the nonlinearity of such a dynamic system, the use of nonlinear dynamics methods allows one to investigate the chaotic nature of processes in the body, represented in the space of states [3].

The paper proposes an approach in which the biomedical signal is presented in the form of time series describing the change in parameters of the cardiovascular system over time. As a biomedical signal, heart rate variability was chosen, which is presented in the form of long-term time series of healthy research participants and processing of the specified data in MATLAB. The interpolation preceding the study of nonlinear characteristics was carried out using the cubic spline interpolation method.

The next stage of signal processing in this work was the construction of the attractor of the phase trajectory of the dynamic system as one of the simplest and most visual ways to assess its chaotic behavior. This method is used for statistical and fractal analysis of the properties of attractors of phase trajectories: if we consider the phase space of an oscillating system, then a finite set of attractor points attracts phase trajectories. Since attractors can be simple, regular, with a constant mode and with non-periodic modes: for complex dynamic systems of biological nature, attractors are endowed with scale invariance. In the literature, they are called "strange" and their criteria are, in turn, the instability of the trajectory in the form of exponential divergence from the gravity zone and fractional dimension [4].

For such complex dynamical systems as living organisms, a strange attractor can be constructed from the time series of a single observed dynamical variable. According to Takens' theorem [4], the main properties of the attractor will be the same as those of the object under study, and its characteristics can be determined by similarity. Graphs of the attractors of the studied HRV signals are shown in fig. 1.

Figure 1 and Figure 2 shows an example of the construction of a strange attractor of heart rate variability, which is presented in the form of long-term time series of healthy research participants. To import the signal into MATLAB, the open database of biomedical signals of the Physionet.org site was used [5]. Time series are formed from biomedical signals of Hotler monitoring during 24 hours to preserve information about biological diurnal variability. The analysis of the type of HRV attractors consists in the analysis of integral processes. such an analysis is based on the interaction between individual components of HRV or between these components in combination with characteristics in other organs and systems, which occurs as a phenomenon of self-organization or synergy.

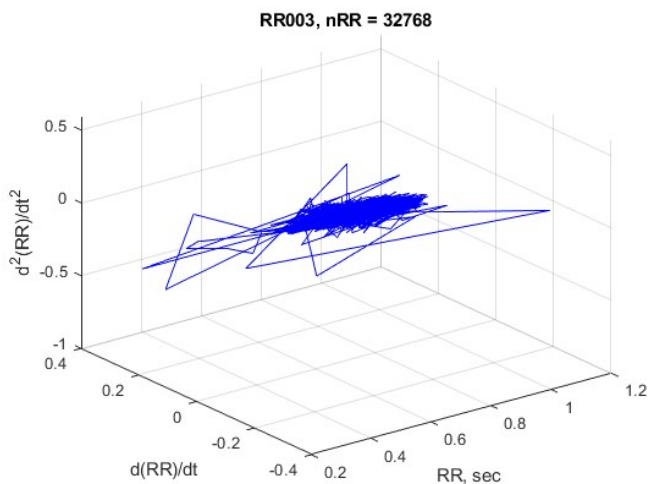


Fig. 1. The first example of building a strange attractor of heart rate variability for signal R00

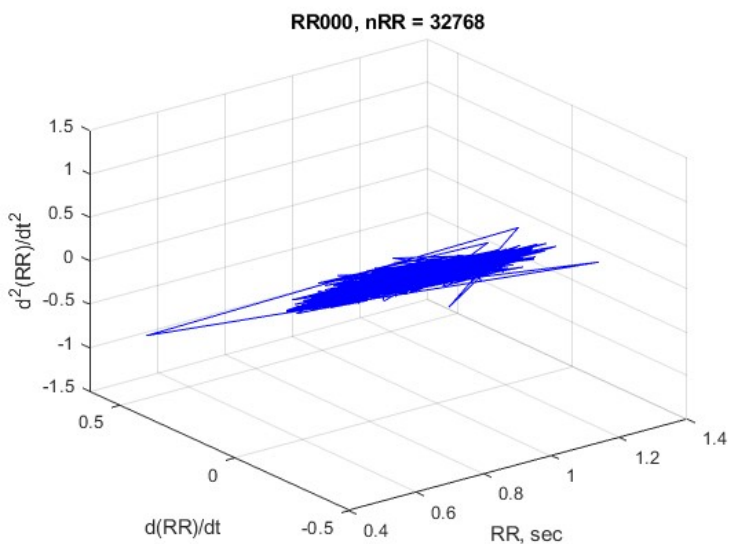


Fig. 2. The first example of building a strange attractor of heart rate variability for signal R03

Thus, the HRV signal attractor is a three-dimensional visualization of the variable and its derivatives of the 1st and 2nd order. Such a visualization gives a clear idea of the dynamics of the process. The resulting graphs clearly demonstrate chaotic behavior and are the solution of a system of three nonlinear differential equations. Although this approach does not allow presenting the solution in an explicit form, it allows qualitatively describing many important features of dynamic biological systems.

References

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КЛІНІКО-ЕКСПЕРТНІ ПИТАННЯ ПРОВЕДЕННЯ ОЦІНЮВАННЯ ЯКОСТІ НАДАННЯ МЕДИЧНИХ ПОСЛУГ

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В роботі розглянуті особливості проведення клініко-експертної оцінки якості надання медичної допомоги та медичного обслуговування шляхом експертизи діагностики, медичного лікування та реабілітації та медичного обслуговування відповідно до вимог клінічних