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METHOD OF THE QUADRATIC INTERPOLATION OF THE DISCRETE RHYTHM FUNCTION OF THE CYCLICAL SIGNAL WITH A DEFINED SEGMENT STRUCTURE

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***Summary**. The article considers the problem of determining the rhythm function of some continuous cyclic function by the means of interpolation of the embedded in it discrete rhythm function, which is defined by the segment structure of the cyclic signal. The method of the quadratic interpolation of the discrete rhythm function is suggested. The necessary analytical values for conducting the partially-quadratic interpolation of the discrete rhythm function have been defined.*

***Key words**: cyclic signal, cyclic random process, segmentation, segment structure, the rhythm function, quadratic interpolation.*

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Problem setting. Events that are characterized by availability of oscillation properties are widely used in the fields of medicine and economics. Such events and processes are called cyclic [1-3] because their spatial-temporal structure consists of series of cycles. This cyclic structure describes deployment of rhythm of an event or a process in time or space. Such structure is diverse and unique for each process or signal. Therefore, development of new methods of diagnostics and simulation modeling of cyclical events, processes and signals is an actual scientific and technical problem.

Analysis of recent researches. In the papers [4, 5, 6] a mathematical model of oscillation events and signals defined as a cyclic function is described, which generalizes the notion of periodic and almost periodic functions for deterministic and stochastic cases, in particular the notion of continuous and discrete random cyclical processes with time-zone structure has been introduced. In the papers [7, 12] it has been shown that the cyclical rhythmic structure of any cyclic function is completely described by the function of rhythm, which describes changes of time intervals between the values of single-phase of the cyclic function. In automated systems of digital processing of cyclical data, including cardio diagnostic, methods of discretization are used [8], statistical analysis [9] and simulation modeling [10] of a cycle signal, which can be used with the predefined rhythm function.

However, in the most tasks of analysis of cyclical rhythm signals their function is unknown, and therefore it is necessary to previously carry out its assessment. In the papers [7, 12] the method of piecewise linear interpolation of rhythm function has been described although in most practical cases, priori nothing is known about the patterns of change in rhythm function inside the segments cycles and the segments-zones of cyclical signal. So, it is naturally, with such uncertainty to use different types of interpolation functions.

Objectives. This article focuses on the problem of evaluation of functions of rhythm, quadratic (parabolic) interpolation of the discrete functions of cyclical rhythm signal with the segment structure.

Main part. In the papers [5, 6] the definition of the cyclical casual process with time-zone structure (segment) has been given. It should be noted that in some works, the term «time-zone structure» is used; this is due to specific application area of the studied signals – cardio-metrics.

In this paper we will use the term «segment structure», since this concept covers and generalizes the notion of the cycle, zone and is directly related to the methods of segmentation, that are needed for the problem of determining the discrete functions of rhythm through the points in time, corresponding to the limits of segments of zones or cycles.

On the stage of segmentation, when the divided segments of signal have not yet passed the identification of belonging to the cycle or to the appropriate zone, they have a generalized name – «segment».

A cyclical casual process $\{\xi(\omega,t),\omega\in\mathbf{\Omega},t\in\mathbf{R}\}$ is called the cyclical casual process with time-zone structure (segment structure) with the function of rhythm $T(t,n)$ which can be represented as (cycles through process-cycle segments)

$$\xi(\omega,t)=\sum_{m\in\mathbf{Z}}\xi_m(\omega,t),\ \omega\in\mathbf{\Omega},\ t\in\mathbf{R}\,, \tag{1}$$

where ω – elementary event; $\mathbf{\Omega}$ – space of elementary events; $\xi_m(\omega,t)$ – corresponds to m – segment cycle of cyclical casual process, which is defined as

$$\xi_m(\omega,t)=\xi(\omega,t)\cdot I_{\mathbf{W}_m}(t),m\in\mathbf{Z},\omega\in\mathbf{\Omega},\ t\in\mathbf{R}\,, \tag{2}$$

where $I_{\mathbf{W}_m}(t)-$ is the indicator function $m-$ is the segment cycle, which is equal to

$$I_{\mathbf{W}_m}(t)=\begin{cases}1,\ t\in\mathbf{W}_m,\\ 0,\ t\notin\mathbf{W}_m.\end{cases} \tag{3}$$

The areas of definition $\mathbf{W}_m$ of the indicator function m (segment) i.e. cycle process are determined by the half interval

$$\mathbf{W}_m=[t_m,t_{m+1}), \tag{4}$$

where t_m- is the start time $m-$ is the segment-cycle process.

In case when each cycle of the cyclical signal contains smaller segments-zones then the random cyclical process can be presented in a form (through the process zones, segments-zones)

$$\xi(\omega,t)=\sum_{m\in\mathbf{Z}}\sum_{j=1}^{N}\xi_{\substack{m\\j}}(\omega,t),\ \omega\in\mathbf{\Omega},\ t\in\mathbf{R}\,, \tag{5}$$

where $\xi_{\substack{m\\j}}(t),\ t\in\mathbf{W}_{\substack{m\\j}}\ -\ j\ -$ is the segment-zone в $m-$ is the cycle of cyclical casual process that is:

$$\xi_{\substack{m\\j}}(\omega,t)=\xi(\omega,t)\cdot I_{\mathbf{W}_{\substack{m\\j}}}(t)=\xi_m(\omega,t)\cdot I_{\mathbf{W}_{\substack{m\\j}}}(t),\ m\in\mathbf{Z},\ j=\overline{1,N},\omega\in\mathbf{\Omega},\ t\in\mathbf{R}\ . \tag{6}$$

where $I_{\mathbf{W}_{\substack{m\\j}}}(t)-$ is the indicator function $j-$ is the segment-zone в $m-$ is the cycle, that is

$$I_{\mathbf{W}_{\substack{m\\j}}}(t)=\begin{cases}1,\ t\in\mathbf{W}_{\substack{m\\j}},\\ 0,\ t\notin\mathbf{W}_{\substack{m\\j}}.\end{cases} \tag{7}$$

Areas of definition $\mathbf{W}_{\substack{m\\j}}$ of indicator function j segment-zone in m cycle process, is determined by half interval

$$\mathbf{W}_{\substack{m\\j}} = \left[t_{\substack{m\\j}}, t_{\substack{m\\j+1}}\right), \tag{8}$$

where $t_{\substack{m\\j}}$ – is the start time j – is a zone in m – is the cycle of process.

Random process (2), which corresponds to m – cycle of cyclical random process, associated with the random process (6), which corresponds to j – segment – zone of cyclical casual process, with the following ratio

$$\xi_m(\omega,t) = \sum_{j=1}^{N} \xi_{\substack{m\\j}}(t),\ t \in \mathbf{W}_m,\ \forall m \in \mathbf{Z}. \tag{9}$$

Areas of definition of the zones and process cycles with segment structure are satisfied with the following ratio

$$\mathbf{W}_m = \bigcup_{j=1}^{N} \mathbf{W}_{\substack{m\\j}},\ \bigcup_{m\in\mathbf{Z}}\bigcup_{j=1}^{N} \mathbf{W}_{\substack{m\\j}} = \mathbf{R},\ \mathbf{W}_{\substack{m\\j}} \neq \varnothing,\ \mathbf{W}_{\substack{m\\j1}} \bigcap \mathbf{W}_{\substack{m\\j2}} = \varnothing,\ j_1 \neq j_2. \tag{10}$$

Segment structure of cyclical casual process is given by multiple points in time, corresponding to the beginnings of segments – zones of cyclical process

$$\mathbf{D}_a = \left\{ t_{\substack{m\\j}},\ m \in \mathbf{Z},\ j = \overline{1,N} \right\},\ t_m = t_{\substack{m\\1}},\ \forall m \in \mathbf{Z}, \tag{11}$$

However for certain points in time the conditions of isomorphism are carried out relatively to the order of samples that correspond to the segments and also equality of attributes of values of segments [5, 6, 12].

$$1)\ t_{\substack{m\\j}} \leftrightarrow t_{\substack{m+1\\j}}, \ldots; t_{\substack{m\\j+1}} > t_{m,j}, t \in \mathbf{W}, m \in \mathbf{Z},\ j = \overline{1,N};$$
$$2)\ p(\xi_\omega(t_{\substack{m\\j}})) = p(\xi_\omega(t_{\substack{m\\j+1}})) \to \mathbf{A}, t \in \mathbf{W}, \omega \in \mathbf{\Omega}, m \in \mathbf{Z},\ j = \overline{1,N},$$

where $\mathbf{A}$ – is the set of attributes, for example, the attribute is the equality of values of all single-phase samples, i.e. the condition is carried out $f(t) = f(t + T(t,n)),\ t \in \mathbf{W}, m \in \mathbf{Z}$ the attribute is the equality of values $p(f(t)) = f(t)$.

In case when the smallest segment of the cyclical random process is its cycle then the segment structure may be defined by a plurality of the points in time of the beginnings of its cycle: $\mathbf{D}_c = \{t_m,\ m \in \mathbf{Z}\}$.

Due to the given set of beginnings of segments zones the discrete function of rhythm can be defined as $T(t_{\substack{m\\j}}, n)$, which is embedded in the continuous $T(t,n)$, that is

$$T(t_{\substack{m\\j}}, n) = t_{\substack{m+n\\j}} - t_{\substack{m\\j}},\ \forall m, n \in \mathbf{Z},\ j = \overline{1,N}. \tag{12}$$

In case, if the smallest segment of the cyclical random process is its cycle, then the discrete function of rhythm will be determined by the moments of beginnings of cycles of random process $\xi(\omega,t)$

$$T(t_m, n) = t_{m+n} - t_m,\ \forall m, n \in \mathbf{Z}. \tag{13}$$

Thus, the information about the beginnings of segments- zones of cyclical random process allows to define its discrete rhythmic structure, information about which is contained in discrete function of rhythm $T(t_{m_j}, n)$, which is embedded in a continuous function of rhythm $T(t,n)$ of cyclical random process of continuous argument. Examples of implementations of cyclical signals and their functions of rhythm is shown in figures 1 – 3.

To determine the set of points in time (11) we will use the method of segmentation [1, 11].

Having got $\mathbf{D}_c = \{t_m, m \in \mathbf{Z}\}$ and $\mathbf{D}_a = \left\{t_{m_j}, m \in \mathbf{Z},\ j = \overline{1, N}\right\}$ we will go to interpolation of discrete functions of rhythm (12) and (13) and evaluate the continuous function of rhythm $T(t,n)$.

Quadratic interpolation of the function of rhythm

Let us consider the type of interpolation – quadratic (or parabolic) interpolation.

Interpolation function of the discrete function of rhythm $\hat{T}(t,1)$ will look like

$$\hat{T}(t,1) = \sum_{m \in \mathbf{Z}} \sum_{j=1}^{N} \hat{T}_{m_j}(t,1),\ t \in \mathbf{R}, \tag{14}$$

where $\left\{\hat{T}_{m_j}(t,1)\right\}$ – is the set of interpolation segments that are equal:

$$\hat{T}_{m_j}(t,1) = a_{m_j} \cdot t^2 + b_{m_j} \cdot t + c_{m_j},\ t \in \mathbf{W}_{m_j}, m \in \mathbf{Z},\ j = \overline{1, N}. \tag{15}$$

Thus, with quadratic interpolation of the function of rhythm it is necessary to find three sets of coefficients $\left\{a_{m_j}, m \in \mathbf{Z},\ j = \overline{1, N}\right\}$, $\left\{b_{m_j}, m \in \mathbf{Z},\ j = \overline{1, N}\right\}$ and $\left\{c_{m_j}, m \in \mathbf{Z},\ j = \overline{1, N}\right\}$, that fully define the interpolation function $\hat{T}(t,1)$ for each of the defined segments.

In the role of interpolation function in the interval $\left[t_{m_j}, t_{m_{j+2}}\right]$ square trinomial is taken (15). To determine the unknown coefficients of which three equations are required (16). We will find expressions for calculating the unknown coefficients of interpolation function. For this we will write the equation of parabola, connecting the points with coordinates $(t_{m_j}; \hat{T}(t_{m_j},1))$, $(t_{m_{j+1}}; \hat{T}(t_{m_{j+1}},1))$ and $(t_{m_{j+2}}; \hat{T}(t_{m_{j+2}},1))$, that is combines the readings of discrete function of rhythm $\hat{T}(t_{m_j},1)$ at the time points $t_{m_j}, t_{m_{j+1}}$ та $t_{m_{j+2}}$:

$$\begin{cases} \hat{T}_{m_j}(t,1) = a_{m_j} \cdot t_{m_j}^{\ 2} + b_{m_j} \cdot t_{m_j} + c_{m_j}, \\ \hat{T}_{m_{j+1}}(t,1) = a_{m_j} \cdot t_{m_{j+1}}^{\ 2} + b_{m_j} \cdot t_{m_{j+1}} + c_{m_j}, \\ \hat{T}_{m_{j+2}}(t,1) = a_{m_j} \cdot t_{m_{j+2}}^{\ 2} + b_{m_j} \cdot t_{m_{j+2}} + c_{m_j}, \end{cases} \tag{16}$$
$$m \in \mathbf{Z},\ j = \overline{1, N-2}$$

According to equations (16), coefficients $\left\{a_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}, \left\{b_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}$ and $\left\{c_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}$ will be determined according to the expressions:

$$c_{m_j} = T(t_{m_j}, 1) - a_{m_j} \cdot t_{m_j}{}^2 - b_{m_j} \cdot t_{m_j},\; m \in \mathbf{Z},\; j = \overline{1, N-2}, \tag{17}$$

$$b_{m_j} = \frac{T(t_{m_{j+1}}, 1) - T(t_{m_j}, 1) - a_{m_j} \cdot (t_{m_{j+1}}{}^2 - t_{m_j}{}^2)}{t_{m_{j+1}} - t_{m_j}},\; m \in \mathbf{Z},\; j = \overline{1, N-2}, \tag{18}$$

$$a_{m_j} = \frac{T(t_{m_{j+2}}, 1) - T(t_{m_j}, 1)}{(t_{m_{j+2}} - t_{m_j}) \cdot (t_{m_{j+2}} - t_{m_{j+1}})} - \frac{T(t_{m_{j+1}}, 1) - T(t_{m_j}, 1)}{(t_{m_{j+1}} - t_{m_j}) \cdot (t_{m_{j+2}} - t_{m_{j+1}})},\; m \in \mathbf{Z},\; j = \overline{1, N-2}. \tag{19}$$

According to the conditions [4, 5, 6], that are imposed on the interpolation function $\hat{T}(t,1)$ its derivative must be greater than – 1, and this is possible only when the derivatives of the functions $\left\{\hat{T}_{m_j}(t,1)\right\}$ will be greater than – 1.

The derivatives of the function $\left\{\hat{T}_{m_j}(t,1)\right\}$ are equal to

$$\hat{T}_{m_j}{}'(t,1) = 2 \cdot a_{m_j} \cdot t_{m_j} + b_{m_j} > -1. \tag{20}$$

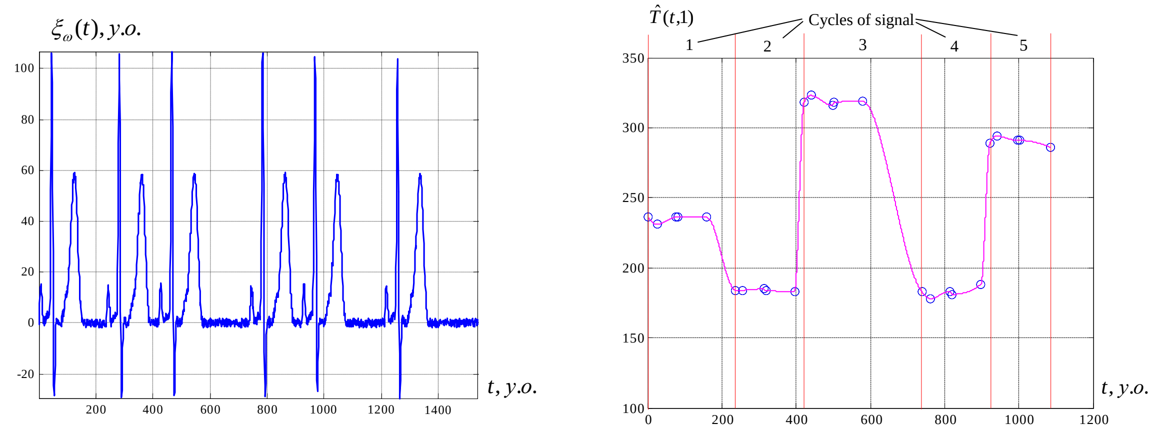
In practice, this condition will not always be performed (20) on the function of the rhythm due to the coefficients $\left\{a_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}$ and $\left\{b_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}$.

Therefore, it is proposed in the method of quadratic interpolation of discrete function of rhythm to use the additional condition (20). After determining the coefficients (17) – (19) it is necessary to check the condition (20), and in cases when it is not done it is necessary to use replacement of quadratic interpolation to the linear one. Thus we can provide a necessary condition for the function of rhythm $\hat{T}'(t,1) > -1$, since for the linear interpolation this condition for the rhythm function is always performed [7].

In such cases for the linear interpolation we will determine the coefficients $\left\{k_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}$ and $\left\{d_{m_j},\, m \in \mathbf{Z},\; j = \overline{1, N}\right\}$, according to the known formulas [7], and interpolation polynomial (15), taking $a_{m_j} = 0$, will look like,

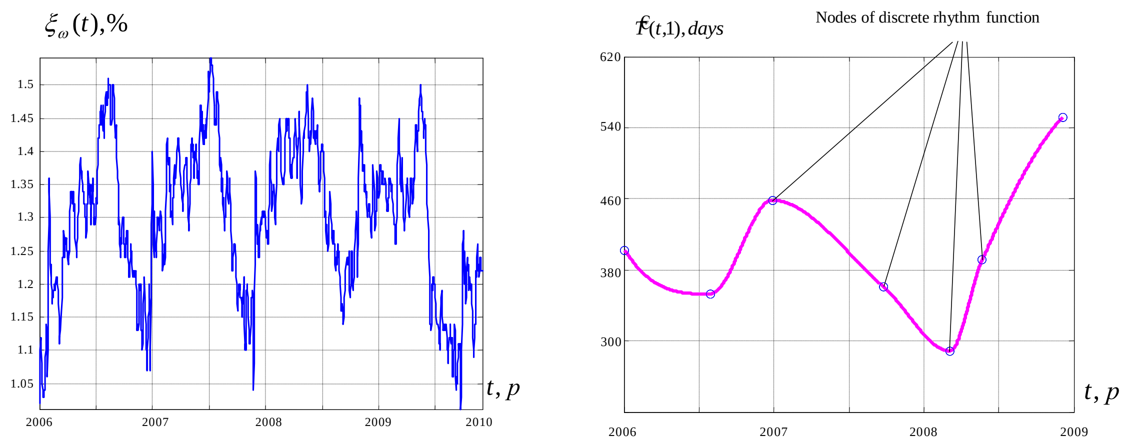
$$\hat{T}_{m_j}(t,1) = k_{m_j} \cdot t + d_{m_j},\; t \in \mathbf{W}_{m_j}, m \in \mathbf{Z},\; j = \overline{1, N}. \tag{21}$$

Let us apply received above values for the evaluation of the function of rhythm of different cyclical signals. Discrete function of rhythm we will get by applying methods of segmentation of cyclical signal [1, 11]. Figure 1 presents the electrocardio signal and discrete function of rhythm (data is given in arbitrary units).



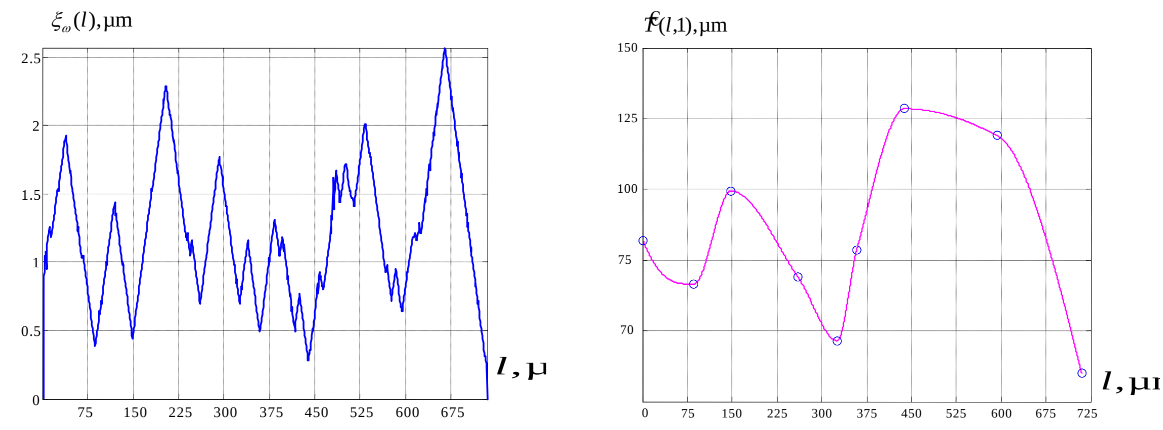
a) b)

Figure 1. Electro cardio signal and the interpolation of its discrete rhythm function
a) Electrocardio signal; b) Result of the partially-quadratic interpolation of the discrete rhythm function



a) b)

Figure 2. Cyclic economic process and the interpolation of its discrete rhythm function
a) Cyclic economic process (USA auto financing activity index); b) Results of the partially-quadratic interpolation of the discrete rhythm function



a) b)

Figure 3. Process of orderly surface creation of a steel model and the interpolation of its discrete rhythm function a) Process of orderly surface creation of a steel model that is processed outdoors (the process is presented in the form "width of the element of the surface - length of the presented area"); b) Results of the partially-quadratic interpolation of the discrete rhythm function

The given method is one of the simple methods for constructing of the interpolation function, which is not always adequately describes the variations of the function of rhythm of real cyclical signals. In this regard it is necessary to develop other methods of interpolation of the function of rhythm e.g. using splines, polynomials of the third order or polynomials of the higher order.

Accuracy of the method of interpolation of discrete function of rhythm depends on many factors [12] primarily depends on the accuracy and correctness of segment structure, points in time of the beginnings of segments – cycles and segments – zones. However, the more the researched signal will include segments – zones on the cycle, the more information about the samples of discrete functions of rhythm we will get and thus it will be more accuracy of its interpolation.

Conclusions. In this paper, the method of piecewise quadratic interpolation function of the cyclical rhythm signal based on consideration of information about its segment structure has been designed. Appropriate calculated formulas to determine the coefficients of the polynomial interpolation have been received. This method of interpolation complements the cyclical signal processing unit and can be used in digital systems of automated processing of data in real cyclic medicine, mechanics or economics.

In further research the accuracy of the developed method of piecewise quadratic interpolation of the rhythm function and the famous (piecewise linear interpolation functions of the discrete rhythm) are going to be examined. The question of choosing the optimal interpolating polynomial remains unexplored: linear or quadratic in the tasks of interpolation of discrete function of rhythm of different cyclical signals, that is also planned in the future researches.

References

1. Lytvynenko I., Lupenko S., Shcherbak L. Statystychnyy metod vyznachennya zonnoyi struktury elektrokardiosyhnalu v avtomatyzovanykh diahnostychnykh systemakh, Visnyk Ternopil's'koho derzhavnoho tekhnichnoho universytetu, Ternopil', 2005, vol. 10, no. 3, pp. 165 – 175. [in Ukrainian].
2. Lytvynenko I.V., Lupenko S.A, Dem’yanchuk N.R., Horkunenko A.B. Imitatsiyne modelyuvannya vzayemopov’yazanykh ekonomichnykh protsesiv na osnovi vektora tsyklichnykh rytmichno pov"yazanykh vypadkovykh protsesiv. Elektronika ta systemy upravlinnya. Natsional'nyy aviatsiynyy universytet, Kyyiv, 2011, vol. 28, no. 2, pp. 133 – 141. [in Ukrainian].
3. Lytvynenko I.V, Marushchak P.O. Analysis of the State of the Modified Nanotitanium Surface with the Use of the Mathematical Model of a Cyclical Random Process. Optoelectronics, Instrumentation and Data Processing, 2015, vol. 51, no. 3, pp. 254 – 263.
4. Lupenko S.A. Determinovani i vypadkovi tsyklichni funktsii yak modeli kolyvalnykh yavyshch i syhnaliv: vyznachennia ta klasyfikatsii. Elektronne modeliuvannia. In-t problem modeliuvannia v enerhetytsi im. H. Ye. Pukhova NAN Ukrainy. Kyiv, 2006, vol. 28, no. 4, pp. 29 – 45. [In Russian].
5. Lupenko S. Vypadkovyy protses iz zonnoyu chasovoyu strukturoyu ta simeystvo yoho funktsiy rozpodilu. Visnyk Ternopil's'koho derzhavnoho tekhnichnoho universytetu, Ternopil', 2005. Vol. 10, no. 4, pp. 183 – 192. [in Ukrainian].
6. Lupenko S. Tsyklichni ta periodychni vypadkovi protsesy iz zonnoyu chasovoyu strukturoyu ta yikh ymovirnisni kharakterystyky. Visnyk Ternopil's'koho derzhavnoho tekhnichnoho universytetu, Ternopil', 2006, vol. 11, no. 2, pp. 150 – 155. [in Ukrainian].
7. Lupenko S.A. Zavdannya interpolyatsiyi funktsiyi rytmu tsyklichnoyi funktsiyi z vidomoyu zonnoyu strukturoyu. Elektronika ta systemy upravlinnya. Natsional'nyy aviatsiynyy universytet. Kyyiv, 2007, vol. 12, no. 2, pp. 27 – 35. [in Ukrainian].
8. Lupenko S. Osoblyvosti dyskretyzatsiyi tsyklichnykh funktsiy. Vymiryuval'na ta obchyslyuval'na tekhnika v tekhnolohichnykh protsesakh, Khmel'nyts'kyy, 2006. No. 1, pp. 64 – 70. [in Ukrainian].
9. Lupenko S.A. Statystychni metody obrobky tsyklichnoho vypadkovoho protsesu. Elektronika ta systemy upravlinnya. Natsional'nyy aviatsiynyy universytet, Kyyiv, 2006. Vol. 8, no. 2, pp. 59 – 65 [in Ukrainian].
10. Lytvynenko I.V., Maruschak P.O., Lupenko S.A. Processing and modeling of ordered relief at the surface of heat-resistant steels after laser irradiation as a cyclical random process. Automatic Control and Computer Science, 2014, vol. 48, no. 1, pp. 1 – 9.
11. Lytvynenko I.V., Maruschak P., Lupenko S., Panin S. Segmentation and Statistical Processing of Geometric and Spatial Data on Self-Organized Surface Relief of Statically Deformed Aluminum Alloy. Applied Mechanics and Materials, 2015, vol. 770, pp. 288 – 293.
12. Lupenko S.A. Teoretychni osnovy modelyuvannya ta opratsyuvannya tsyklichnykh syhnaliv v informatsiynykh systemakh. Monohrafyya, L'viv, Mahnoliya 2006, 2016. 343 p. [in Ukrainian].

Список використаної літератури

1. Литвиненко, Я. Статистичний метод визначення зонної структури електрокардіосигналу в автоматизованих діагностичних системах [Текст] / Я. Литвиненко, С. Лупенко, Л. Щербак // Вісник Тернопільського державного технічного університету. – Тернопіль, 2005. – Т. 10, № 3. – С. 165 – 175.
2. Литвиненко, Я.В. Імітаційне моделювання взаємопов'язаних економічних процесів на основі вектора циклічних ритмічно пов'язаних випадкових процесів [Текст] / Я.В. Литвиненко, С.А. Лупенко, Н.Р. Дем'янчук, А.Б. Горкуненко // Електроніка та системи управління / Національний авіаційний університет. – Київ, 2011. – № 2 (28). – С. 133 – 141.
3. Lytvynenko I.V , Marushchak P.O. Analysis of the State of the Modified Nanotitanium Surface with the Use of the Mathematical Model of a Cyclical Random Process. Optoelectronics, Instrumentation and Data Processing, 2015, vol. 51, no. 3, pp. 254 – 263.
4. Лупенко, С.А. Детерминированные и случайные циклические функции как модели колебательных явлений и сигналов: определение и классификация [Текст] / С.А. Лупенко // Электронное моделирование / Ин-т проблем моделирования в энергетике им. Г.Е. Пухова НАН Украины. – Киев, 2006. – Т. 28, № 4. – С. 29 – 45.
5. Лупенко, С. Випадковий процес із зонною часовою структурою та сімейство його функцій розподілу [Текст] / С. Лупенко // Вісник Тернопільського державного технічного університету. – Тернопіль, 2005. – Т. 10, № 4. – С. 183 – 192.
6. Лупенко С. Циклічні та періодичні випадкові процеси із зонною часовою структурою та їх ймовірнісні характеристики [Текст] / С. Лупенко // Вісник Тернопільського державного технічного університету. – Тернопіль, 2006. – Т. 11, № 2. – С. 150 – 155.
7. Лупенко, С.А. Завдання інтерполяції функції ритму циклічної функції з відомою зонною структурою [Текст] / С.А. Лупенко // Електроніка та системи управління / Національний авіаційний університет. – Київ, 2007. – № 2 (12). – С. 27 – 35.
8. Лупенко, С. Особливості дискретизації циклічних функцій [Текст] / С. Лупенко // Вимірювальна та обчислювальна техніка в технологічних процесах. – Хмельницький, 2006. – № 1. – С. 64 – 70.
9. Лупенко, С.А. Статистичні методи обробки циклічного випадкового процесу [Текст] / С.А. Лупенко // Електроніка та системи управління / Національний авіаційний університет. – Київ, 2006. – № 2 (8). – С. 59 – 65.
10. Lytvynenko I.V., Maruschak P.O., Lupenko S.A. Processing and modeling of ordered relief at the surface of heat-resistant steels after laser irradiation as a cyclical random process. Automatic Control and Computer Science, 2014, vol. 48, no. 1, pp. 1 – 9.
11. Lytvynenko I.V., Maruschak P., Lupenko S., Panin S. Segmentation and Statistical Processing of Geometric and Spatial Data on Self-Organized Surface Relief of Statically Deformed Aluminum Alloy. Applied Mechanics and Materials, 2015, vol. 770, pp. 288 – 293.
12. Лупенко, С.А. Теоретичні основи моделювання та опрацювання циклічних сигналів в інформаційних системах: Монография [Текст] / Лупенко С.А. – Львів : В-во Магнолія 2006, 2016. – 343 с.

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МЕТОД КВАДРАТИЧНОЇ ІНТЕРПОЛЯЦІЇ ДИСКРЕТНОЇ ФУНКЦІЇ РИТМУ ЦИКЛІЧНОГО СИГНАЛУ ІЗ ВИЗНАЧЕНОЮ СЕГМЕНТНОЮ СТРУКТУРОЮ

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Резюме. *Розглянуто задачу визначення функції ритму деякої неперервної циклічної функції шляхом інтерполяції вкладеної в неї дискретної функції ритму, яка визначається сегментною структурою циклічного сигналу. Запропоновано метод квадратичної інтерполяції функції ритму. Встановлено необхідні аналітичні співвідношення для проведення кусково-квадратичної інтерполяції дискретної функції ритму.*

Ключові слова*: циклічний сигнал, сегментна структура, функція ритму, квадратична інтерполяція.*

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