ГІПОТЕЗИ. НЕСТАНДАРТНІ МЕТОДИ РІШЕННЯ НАУКОВИХ ТА ІНЖЕНЕРНИХ ПРОБЛЕМ ПРИЛАДОБУДУВАННЯ

DOI: https://doi.org/10.20535/1970.68(2).2024.318684
UDC 621.9.08

PHANTOM CHAINS TONTOR OF BIONIC OBJECT'S MOVEMENTS OF AUTOMATED SYSTEMS. Part 2

Volodymyr Skytsiouk, and Tatiana Klotchko
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»
Kyiv, Ukraine
E-mail: t.klochko@kpi.ua

In our previous author's works such properties of the phantom step as its length and curvature relative to the imaginary plane were considered. All these parameters were considered within clearly defined coordinates associated with the beginning and end of the step.

Analytical and graphical models were obtained in this work, which are based on mathematical approaches to determining the spatiotemporal characteristics of the movement of objects taking into account the characteristics of phantom chains of bionic systems. Therefore, the application of the obtained models provides prospects for obtaining precise parameters of the movement of the final real technological object in the working space when performing complex kinematics of movements.

At the same time, the dependences of the relationship between the volumes of technological abstract and their formed phantoms were investigated, which provide the opportunity to describe positive and negative technologies that are currently promising in modern production and the realities of the application of bionic automated equipment for various purposes.

The results of our research can be used as a basis for obtaining new analytical models that determine the motion characteristics of dynamic abstract objects depending on the scope of application. This has the ultimate goal of being able to determine different types of motion of bionic objects, which is associated with automated systems in industry, medicine, implementation of technological processes, and scientific research.

The prospects for further scientific research on this problem regarding the development of bionic automated systems, devices and objects are to continue the creation of analytical models of these objects with a view to their application in various areas and at different stages of the life cycle of technological objects, which improves production processes, as well as complex bionic systems for medical purposes.

Keywords*: phantom TONTOR chains; bionic devices; automated systems; object; movement trajectory; the process of stepping; unit cycles.*

Introduction

As was stated in part 1 of this work [1], there is an urgent problem of research into the functioning of precision objects, the main application of which is the automation of various processes. These include problems related, firstly, to production tasks, and secondly, to the problems of automating the workspace when performing complex kinematically complex movements of abstract objects [2, 3, 4].

These objects and their functioning processes must ensure the accuracy of technological operations in various areas of use. The main tasks in this case are to ensure the consistency of real objects and their models (phantoms), which corresponds to the technical regulations of their operation. At the same time, such objects may have the character of performing medical functions intended for conducting scientific and analytical medical research [5, 6, 7, 8], as well as the functions of production automated systems [9, 10, 11, 12, 13].

Problems related to the accuracy of the functioning of technological objects and systems, as previously proven by the authors [14, 15, 16, 17], depend on the modeling of those processes that are defined as dynamic, as well as on the degree of accuracy of obtaining an information image and its detailing. Thus, based on the analysis of TONTOR models, i.e., the description and study of phantoms of real objects, the main analytical approaches to increasing the capabilities of precision automated systems were obtained.

At the same time, it is necessary to determine the role of bionic approaches to the development of automated modules and systems that ensure accurate functioning, fulfillment of specified operating characteristics of technological processes. This applies to the creation of manipulators for industrial equipment, for medical systems of such a purpose as surgical complexes, as well as such an important application as bionic prosthetics. In any of these applications of automated systems, an important parameter is the dynamics of movement of such manipulators, and sometimes the entire system.

Therefore, the problem of determining spatial coordinates and the interaction of system components, objects, their location and behavior during the performance of work functions is an important task in creating new automated systems and improving existing ones with the possibility of their further modernization.

Formulation of problem

So, we have considered the facts and theses of the existence of a technological phantom in previous research [1, 14, 15, 16, 17]. As a result of these investigations, it was found out that a phantom as such is the image-function, on which either the action or the form of an object and its physical properties are built.

A very important problem remains the justification of models of spatial motion of the phantom of abstract objects, which provides the opportunity to develop new bionic automated technology. Therefore, the purpose of this work is to study such parameters as the dependence of the volume of the abstract entity and its phantom, as well as the dynamics of phantom steps formed.

These models provide approaches to increasing the accuracy of the operation of moving modules of bionic automated systems, which allows their application in such areas of activity as medicine, industry, and transport automated systems.

Dependencies of an abstract entities volume and its technological phantom

The main task of a technological phantom is to form a shell with certain properties. Currently, such a shell (form) can exist independently until there is a need for its use. In addition, in this case, the shell is filled with material mass so that the object has the opportunity to perform the planned functions.

In any case, the phantom is responsible for organizing the shape of the object. However, the physics of this process is still unknown and requires relevant research.

For example, we can build a model of the existence $Q(x, y, z)$ of a phantom object. To do this, we will assume that the shape and volume of the phantom can be described through a level surface, i.e. $f(x, y, z) = c$, where $c = const$. In this case, if is a P point on this surface, then the vector function will be defined as the radius - vector $\mathbf{q} = \mathbf{q}(P) = \mathbf{q}(\mathbf{r})$, where the radius vector of the point will be $\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$.

In coordinate form this is $\mathbf{q} = q_x\mathbf{i} + q_y\mathbf{j} + q_z\mathbf{k}$, where

$q_x = q_x(x, y, z)$
$q_y = q_y(x, y, z)$
$q_z = q_z(x, y, z)$

are the projections of the vector **a** onto the coordinate axes.

In this case, the lines of force or flux lines are found from the system of differential equations

$$\frac{dx}{q_x} = \frac{dy}{q_y} = \frac{dz}{q_z} \cdot$$

The vector's flow $a(P)$ through the surface *S*, in the direction determined by the unit normal vector $n\{\cos\alpha, \cos\beta, \cos\gamma\}$, to the surface is determined by the integral

$$\iint_S \mathbf{qn}dS = \iint_S \mathbf{q}_n dS = \iint_S (q_x \cos\alpha + q_y \cos\beta + q_z \cos\gamma) dS \cdot$$

Therefore, if is a closed surface that encloses the volume *Q*, and **n** is the unit vector of the external normal, then Ostrogradsky–Gauss formula [18] is valid, which has the following vector form

$$\oiint_S q_n dS = \iiint_{(Q)} div\mathbf{q}dxdydz$$

From this formula, we obtain the dependence - the relationship between the volume *Q* of a body and the surface area *S* that limits it

$$Q = \frac{1}{3}\iint_S (q_x \cos\alpha + q_y \cos\beta + q_z \cos\gamma) dS \cdot$$

From this dependencies it is clearly seen that such parameters of an abstract object as its volume, surface area and vector flow are mutually dependent physical parameters. Thus, we have a phenomenon, when the ends of the field vectors hold the surface of the abstract object on themselves.

Thus, we have the opportunity to consider several options for the properties of the vector field of an object under simple dependencies of vector functions. Currently, the simplest case is a sphere when $\mathbf{q} = \mathbf{r}$. In this case, the divergence and vector will be $div\mathbf{r} = 3$ and $rot\mathbf{r} = 0$ respectively.

A more complicated case is when $\mathbf{q} = \mathbf{rc}$, where **c** is a constant spatial vector. As a result, we obtain the following dependences for divergence and vortex

$$div(\mathbf{rc}) = \frac{\mathbf{rc}}{r}; \quad rot(\mathbf{rc}) = \frac{\mathbf{r} \times \mathbf{c}}{r} \cdot$$

The most complicated case is obtained, when the generating vector is functionally dependent, i.e. $\mathbf{q} = f(\mathbf{r})\mathbf{c}$.

In this case, we obtain the following result for divergence and vortex

$$divf(f(\mathbf{r})\mathbf{c}) = \frac{f'(\mathbf{r})}{r} \cdot (\mathbf{cr});$$

$$rotf(f(\mathbf{r})\mathbf{c}) = \frac{f'(\mathbf{r})}{r} \mathbf{c} \times \mathbf{r} \cdot$$

In a rather simplified view, we can assume that the radius vector in the previous cases marks with its end a series of points that correspond to different coordinates of the phantom surface with the volume *Q*. The external shape and surface of the object correspond to its phantom image function **U**, therefore the origin of the phantom shell can be described as

$$div\mathbf{Q} = [\mathbf{S}]\mathbf{U},$$
$$rot(\mathbf{U}[\mathbf{S}]) = \frac{\mathbf{U}'}{U} \cdot ([\mathbf{S}] \times \mathbf{U}).$$

In this case, the principle of minimal displacements is used.

Nevertheless, despite all these mathematical explorations, we are interested in the volume occupied by the technological phantom. For this, we will use the d'Alembert principle and the principle of minimal displacements.

So, we have a Pandan zone of the technological phantom, which coincides with the Pandan zone of the object up to the limits of the microPandan zone at the atomic level. That is, the surface of the phantom coincides with the surface of the real object up to the limit allowed by Van der Waals forces. So, if we did not count from the outside or from the inside, we get the result of the measurement accuracy of the value $[\mathbf{S}]$. Thus, as a result, the volume of the shell is the difference between the outer and inner Pandan zones.

The divergence between the Pandan zones will be the surface volume of the technological phantom

$$div\mathbf{Q}[-div]\mathbf{Q} = [\mathbf{S}]S, \tag{1}$$

$\mathbf{Q}[$ - external Pandan zone of the object,

$\mathbf{Q}]$ - internal Pandan zone of the object,

S - surface area of an object.

Thus, equation (1) gives the dependence of the technological phantom on the difference between the Pandan zones of the abstract entity.

At the same time, this equation provides the possibility of describing positive and negative technologies. In this case, the surface must be perceived as one to which the surfaces of the Pandan zones approach infinitely from both sides.

Model of Phantom's step dynamics

In previous works [1, 14, 15, 17], such properties of the phantom step as its length and curvature relative to the imaginary plane were considered. All these parameters were considered within clearly defined coordinates associated with the beginning and end of the step.

But despite these studies, we have not determined the process of movement within the step. Movement within the step has a rather specific nature, the essence of which lies in the processes of acceleration and deceleration. In addition, at the "start" (*A*) point, the acceleration has a positive character and increases to a maximum, after which it decreases to zero and changes sign.

These processes were considered in [14, 16], when phantom touching of object surfaces was studied. At the same time, the surfaces of objects had phantom properties. The essence of these properties was that real processes were considered as non-destructive, although the analytical models of consideration were of an imaginary nature, i.e. phantom $\mathbf{\Phi}^{I}$ and $\mathbf{\Phi}^{II}$ [1].

In order to understand what happens during walking, let's consider a simplified problem of linear motion (Fig. 1), when there is a unique direction from point *A* to point *B*. In this case, all steps are the same $[\overline{\mathbf{K}}] = const$, as is the speed at each step $k_i \cdot V_p = const$. This speed is the maximum that the object system can create.

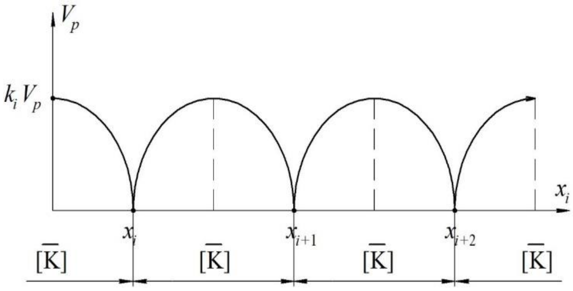

Fig. 1. Linear stepping model

With this method of movement, the maximum speed of movement is achieved in the middle of the step. At stopping points (x_i etc.) the speed is zero.

All this is similar to the touching of two objects, which was considered in [14, 16]. But there are also differences. In [14] we considered single-point touches of the phantom surface in a certain coordinate of the object surface. In our case, in the relative coordinates of the step, we have from point $-[\overline{\mathbf{K}}]/2$ to point "0" "acceleration", and from point "0" to the point $[\overline{\mathbf{K}}]/2$ of braking (Fig. 2).

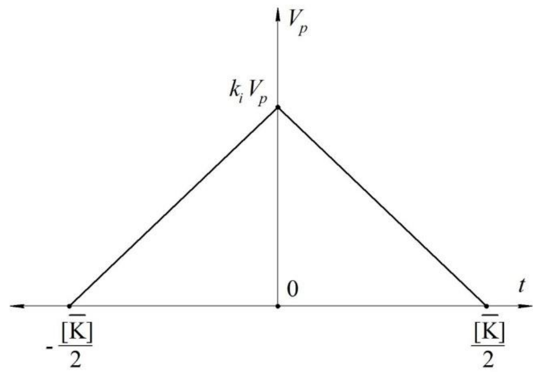

Fig. 2. Velocity versus time diagram within a step

The processes of acceleration and braking occur according to linear laws, i.e.

$$V_p = k_i \alpha_p t,$$

where α_p is the acceleration, and t is the time.

But for our case, we need the dependence of the speed on the distance traveled. In this case, the speed will be defined as

$$V_p = \sqrt{2\alpha_p x}\,.$$

In this case, the diagram of the dependence of speed on the distance traveled takes the form of a half-parabola (Fig. 3).

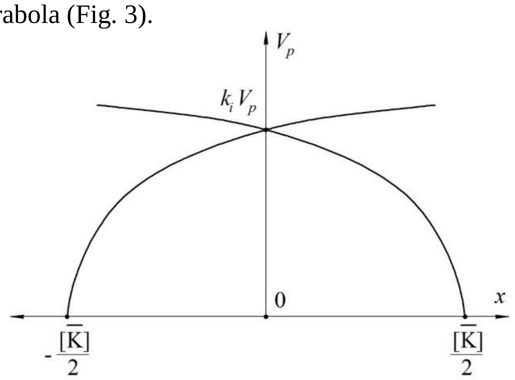

Fig. 3. Velocity versus path diagram

In addition, the branches of the parabolas are directed towards each other, and the poles are located within the coordinates $\pm[\overline{\mathbf{K}}]/2$.

As a result, the velocity trajectory can be represented as parts of two parabolas:

- for the right part

$$k_i V_p = \sqrt{-2k_i\alpha_p\left(x - \frac{[\overline{\mathbf{K}}]}{2}\right)},$$

- for the left part

$$k_i V_p = \sqrt{2k_i\alpha_p\left(x + \frac{[\overline{\mathbf{K}}]}{2}\right)}.$$

In any case, the trajectory cannot have breaks, such as in Fig. 2 and Fig. 3, although the mathematical description of acceleration and deceleration has the form $y = k_i|x|$. This can be seen if the motion function is expanded into a series within the step size $[\overline{\mathbf{K}}]$, i.e.

$$y = \frac{[\overline{\mathbf{K}}]}{4} - \frac{8}{[\overline{\mathbf{K}}]}\left(\cos\frac{\pi x}{[\overline{\mathbf{K}}]} + \cos\frac{3\pi x}{9[\overline{\mathbf{K}}]} + \cos\frac{5\pi x}{25[\overline{\mathbf{K}}]} + \ldots\right)$$

Discarding insignificant terms of the series and simplifying the equation, we obtain the following dependence

$$y = \frac{8}{[\overline{\mathbf{K}}]}\left(\frac{[\overline{\mathbf{K}}]^2}{32} - \cos\frac{\pi x}{[\overline{\mathbf{K}}]}\right)$$

This equation is a parametric representation of a regular cycloid, which in Cartesian coordinates has the following equations:

$$a\cos\left(\left(x + \sqrt{y(2a - y)}\right)/a\right) = a - y$$

or

$$k_i V_p \cos\left(\left(x + \sqrt{y(2k_i V_p - y)}\right)/k_i V_p\right) = k_i V_p - y\,.$$

The cycloid can be elongated and shortened. In our case, since the shortened cycloid is a velocity diagram without braking, we are not interested in it. More often there are cases with an elongated cycloid, when double contact is performed [14, 17].

In this case, such a diagram is typical for cases where the coordinate of the object stretching is refined at each step. Unlike the usual touch, the object reverses the movement, determining the coordinate through two others that are nearby.

The next option for describing the velocity diagram can be an ellipse, if you use the radius vector method r_1 and r_2. Currently, these vectors can be drawn from foci that are located at some distance from the origin. In this case, these radii can be written as

$$r_1 = \sqrt{(x + c)^2 + y^2}\,.$$
$$r_2 = \sqrt{(x - c)^2 + y^2}$$

According to the definition of an ellipse, the sum of these radii is a constant, i.e.

$$r_1 + r_2 = \sqrt{(x + c)^2 + y^2} + \sqrt{(x - c)^2 + y^2} = [\overline{\mathbf{K}}].$$

After a series of transformations we get

$$\frac{4x^2}{[\overline{\mathbf{K}}]^2} + \frac{y^2}{[\overline{\mathbf{K}}]^2 - c^2} = 1.$$

After substitution $k_i V_p = [\overline{\mathbf{K}}]^2 - c^2$ we get

$$\frac{4x^2}{[\overline{\mathbf{K}}]^2} + \frac{y^2}{(k_i V_p)^2} = 1$$

Solving this equation with respect to velocity, we obtain the following dependence for the *i*-th step

$$V_i(x) = \left|\frac{2k_i V_p}{[\overline{\mathbf{K}}]}\sqrt{[\overline{\mathbf{K}}]^2 - x^2}\right|. \qquad (2)$$

The graph of the function (2) is shown in Fig.4.

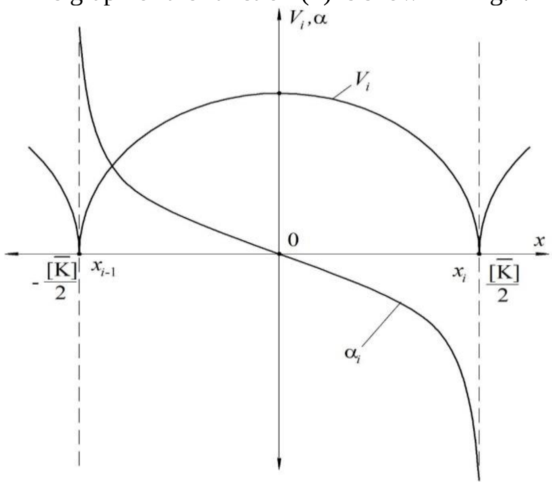

Fig. 4. Velocity and acceleration diagrams within the step distance

If we differentiate the function $V_i(x)$, we will obtain the acceleration diagram during the movement of the object within the step.

Now the acceleration diagram is shown in the same Fig.4 and the velocity dependence by equation (2):

$$\alpha_i = -\frac{k_i V_p \cdot x}{2[\overline{\mathbf{K}}]\sqrt{[\overline{\mathbf{K}}]^2 - x^2}} \tag{3}$$

Especially important when walking is the reference to the coordinate. But there is a problem of determining this coordinate.

In our case, between the points of contact there is a distance within the step. This distance is controlled by the size at each step. That is, in our case, we deploy multiple single-point contact into a curvilinear movement [14].

Therefore, the entry and exit from the coordinate point x_i occurs according to the parabolic diagram (Fig. 5).

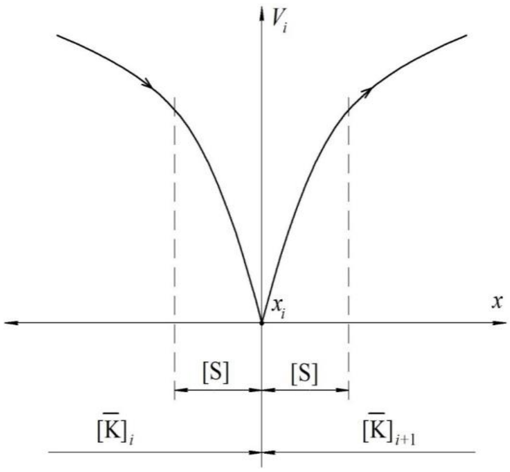

Fig. 5. Velocity diagram when moving from step to step without transition

The coordinate x_i is located within the error of determining the surface **[S]**. In this case, in order to determine the coordinate x_i, the entry into the tangency between the abstract entity must occur within the value **[S].**

So, the entry into the touch occurs at the coordinate x_i**–[S]**. The exit from the coordinate occurs with the same principle, but in magnitude x_i**+[S]** in the direction of movement. But the touch surface is located even earlier than x_i**–[S]**, since, having elastic properties, it must react accordingly until the sensor generates a signal that the surface is registered. This registration process in time is shown in Fig. 6.

In this case, the real coordinate of the surface is much closer than the coordinate x_i**–[S]**. When leaving the touch, that is, from the moment the coordinate is determined, everything happens in the same order, only the time intervals are used to perform other functions.

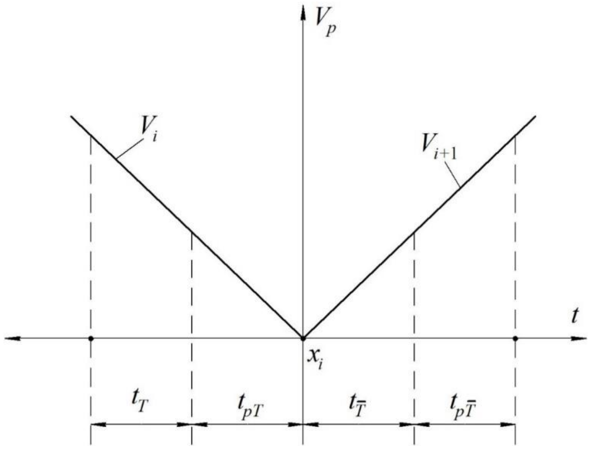

Fig. 6. The process of registering the coordinate of a step in time

When entering the zone of presence of the coordinate x_i, it is necessary to feel the substance that determines the location of the coordinate x_i. This happens as follows. Registration of the surface begins at a distance **[S]**. from the coordinate x_i. But the pressure power in this coordinate is zero.

In the process of movement it grows in such a way that over time t_{T} it can be unambiguously stated that the process of fixing the coordinate $x_i - t_{p\mathrm{T}}$ has taken place and now it is necessary to make a decision to stop. For this, it is necessary to spend time - making a decision to stop and fixing the coordinate x_i. All this time the object continues to move and stops at the coordinate x_i. Therefore, the real surface is not at the coordinate but much earlier, that is, by the value **[S]**.

Thus, the coordinate x_i is imaginary. Further actions consist in creating the next step. To do this, it is necessary to exit the coordinate x_i. This occurs by accelerating the abstract object from the coordinate with speed (Fig.6).

In this case, the exit from the coordinate is fixed for time $t_{\overline{\mathrm{T}}}$. After which a decision is made on further acceleration for time $t_{\overline{\mathrm{T}}}$. During this time $(t_{\overline{\mathrm{T}}} + t_{p\overline{\mathrm{T}}})$, the system moves this distance **[S]**. Thus, we obtain the uncertainty of the coordinate x_i within ±**[S]**. In this case, it is necessary to determine that this error is maintained for each step $[\overline{\mathbf{K}}]$.

It is quite easy to see, that it is practically impossible to maintain such accuracy during braking and acceleration, that is, the diagrams Fig.4, Fig.5, Fig.6 are phantom.

In reality, all abstract objects use the definition of the coordinate by the movement with the flow, as shown in Fig. 7.

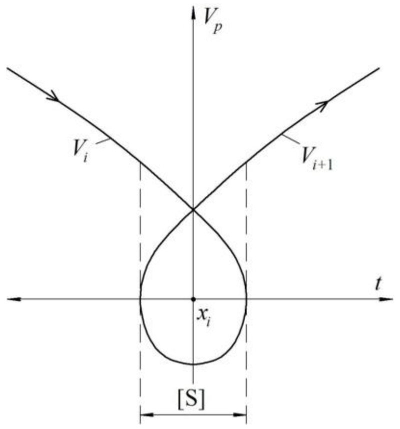

Fig. 7. Diagram of the speed of movement according to the method with the course of the coordinate

In this case, the accuracy of the coordinate definition increases to **[S]**/2.

The result is the ability to determine various types of motion of bionic objects, which is associated with automated systems in industry, medicine, the implementation of technological processes, scientific research.

Conclusions

Analytical and graphical models were obtained, which are based on mathematical approaches to determining the spatio-temporal characteristics of the movement of objects taking into account the characteristics of phantom chains of bionic systems.

Therefore, the application of the obtained models provides prospects for obtaining precise parameters of the movement of the final real technological object in the working space when performing complex kinematics of movements.

At the same time, the dependences of the relationship between the volumes of technological abstract and their formed phantoms were investigated, which provide the opportunity to describe positive and negative technologies that are currently promising in modern production and the realities of the application of bionic automated equipment for various purposes.

Prospects for further scientific research on this problem regarding the development of bionic automated systems, devices and objects consist in continuing to create analytical models of these objects with a view to their application in various areas and at different stages of the life cycle of technological objects, which improves production processes, as well as complex bionic systems for medical purposes.

References

[1] V.I. Skytsiouk, & T.R. Klotchko, “Phantom chains tontor of bionic object's movements of automated systems. Part 1,” *Bull. Kyiv Polytech. Inst. Ser. Instrum. Mak.*, is. 67(1), pp. 109–117, Jun. 2024. DOI: https://doi.org/10.20535/1970.67(1).2024.307410.

[2] T. Takamori, K. Tsuchiya. *Robotics, Mechatronics and Manufacturing Systems.* Elsevier, 2012. 977 p.

[3] Edinbarough, R. Balderas, S.Bose, “A vision and robot based on-line inspection monitoring system for electronic manufacturing”, *Computers in Industry*, vol. 56, no. 8-9, pp. 986–996, 2005. DOI: 10.1016/j.compind.2005.05.022.

[4] T. Westermann and R. Dumitrescu, “Maturity model-based planning of cyber-physical systems in the machinery and plant engineering industry,” in *Proceedings of International Design Conference, DESIGN*, vol. 6, pp. 3041-3052. 2018. DOI: https://doi.org/10.21278/idc.2018.0260.

[5] Deng, Hua, et al. "Slippage and deformation preventive control of bionic prosthetic hands." *IEEE/ASME Transactions on Mechatronics* 22.2 (2017): 888-897. https://ieeexplore.ieee.org/document/7782747.

[6] Jeffrey L. Gunter,a Matt A. Bernstein, Brett J. Borowski, Chadwick P. Ward,Paula J. Britson, and Joel P. Felmlee, Norbert Schuff and Michael Weiner, Clifford R. Jack, “Measurement of MRI scanner performance with the ADNI phantom”, *Medical Physics*, vol. 36, no. 6, pp. 2193- 2205, June 2009. DOI: 10.1118/1.3116776.

[7] Larry A. DeWerd, Michael Kissick, Editors. The Phantoms of Medical and Health Physics. Devices for Research and Development. New York: Springer Science+Business Media, 2014. doi: 10.1007/978-1-4614-8304-5.

[8] Michał Ziemczonok, Arkadiusz Kuś, Piotr Wasylczyk, and Małgorzata Kujawińska, “3D-printed biological cell phantom for testing 3D quantitative phase imaging systems”, Sci Rep. 2019; 9: 18872. Published online 2019 Dec 11. DOI: 10.1038/s41598-019-55330-4.

[9] Maritoni Litorja, “Conversion of imager-specific response to tissue phantom fluorescence into system of units-traceable units”, Journal of Biomedical Optics, vol. 27, is. 7, 074715, May 2022). DOI: 10.1117/1.JBO.27.7.074715.

[10] Jérémie Barral and Pascal Martin, “Phantom tones and suppressive masking by active nonlinear oscillation of the hair-cell bundle” in Proc, Nat. Acad, Sci, USA, 2012 May 22; 109(21): E1344-E1351. Published online 2012 May 3. https://doi.org/10.1073/pnas.1202426109.

[11] Marco Vassallo, “Exploring boundaries of correct specifications in cognitive causal models: phantom path analysis may help”, *Council for agricultural research and economics, crea TPM*, vol. 27, no. 1, pp. 21-42, March 2020. DOI:10.4473/TPM27.1.2 – © 2020.

[12] Jaš Bensa and Marko Žnidaric, “Two-step phantom relaxation of out-of-time-ordered correlations in random circuits”, *Physical review*

research, 4, 013228, 2022. DOI: 10.1103/PhysRevResearch.4.013228.

[13] Oleh Pihnastyi, “Analytical methods for designing technological trajectories of the object of labour in a phase space of states,” *Scientific Bulletin of National Mining University*, no 4, pp. 104-111, 2017.

[14] G.S. Tymchik, V.I. Skytsiouk, M.A. Weintraub, T.R. Klotchko. *Physical bases of TONTOR technology*. Kyiv, Ukraine : NTUU KPI, 2010. (in Ukrainian)

[15] V. Skytsiouk, and T. Klotchko, “Basic principles of spatial position of imaginary and real TONTOR step”, *Bull. Kyiv Polytech. Inst. Ser. Instrum. Mak.*, is. 63(1), pp. 100–106, 2022. DOI: 10.20535/1970.63(1).2022.260659.

[16] Тимчик Г.С., Скицюк В.І., Клочко Т.Р. *Теорія біотехнічних об’єктів. Том 2. Динаміка польових взаємодій об’єктів*. Київ, Україна: ТОВ “Інтердрук”, 2017. 224 с. (in Ukrainian)

[17] V.I. Skytsiouk, & T.R. Klotchko, “Ellipsoidal TONTOR step model of sensors for automated mechatronic systems,” *Bull. Kyiv Polytech. Inst. Ser. Instrum. Mak.*, is. 65 (1), pp. 128-133, 2023. DOI: 10.20535/1970.65(1).2023.283468.

[18] Granino A. Korn, Theresa M. Korn. Mathematical Handbook for Scientists and Engineers: Definitions, Theorems, and Formulas for Reference and Review (Dover Civil and Mechanical Engineering). 2 Revised Edition, (2000), 1152.

УДК 621.9.08

В. І. Скицюк, Т. Р. Клочко

Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», Київ, Україна

ФАНТОМНІ ТОНТОР ЛАНЦЮГИ РУХУ БІОНІЧНИХ ОБ’ЄКТІВ АВТОМАТИЗОВАНИХ СИСТЕМ. Частина 2

У попередніх роботах авторів розглядалися такі властивості фантомного кроку, як його довжина та кривизна відносно уявної площини. Усі ці параметри розглядалися в чітко визначених координатах, пов’язаних з початком і кінцем кроку, але у зв’язку з поставленими задачами в частині 1 роботи продовжено дослідження з визначення особливостей динаміки фантомних ланцюгів системи.

Отримано аналітичні та графічні моделі, які базуються на математичних підходах до визначення просторово-часових характеристик руху об’єктів з урахуванням характеристик фантомних ланцюгів біонічних систем. Отже, застосування отриманих моделей відкриває перспективи для отримання точних параметрів руху кінцевого реального технологічного об’єкта в робочому просторі при виконанні складної кінематики рухів.

При цьому досліджено залежності співвідношення між обсягами технологічного абстракту та їх сформованими фантомами, які дають можливість описати позитивні та негативні технології, перспективні на даний момент у сучасному виробництві та реалії застосування біонічної автоматизованої техніки. для різних цілей.

Перспективи подальших наукових досліджень даної проблеми щодо розробки біонічних автоматизованих систем, пристроїв та об’єктів полягають у продовженні створення аналітичних моделей цих об’єктів з метою їх застосування в різних сферах та на різних етапах життєвого циклу технологічних об’єктів, яка покращує виробничі процеси, а також складні біонічні системи медичного призначення.

Ключові слова: фантомні ТОНТОР ланцюги; біонічні прилади; автоматизовані системи; абстрактний об'єкт; траєкторія руху; процес крокування; одиничні цикли.

*Надійшла до редакції
15 вересня 2024 року*

*Рецензовано
17 жовтня 2024 року*