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**DETERMINATION OF DIAGNOSTIC SIGNS OF MULTIPLE SCLEROSIS
USING TONTOR STEP MODEL**

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The conducted theoretical studies provide a basic thesis regarding the creation of a generalized concept of diagnosis of the signs of multiple sclerosis, which should determine the parameters of the distortion of the idealized model of the body system by the real nature of the disease and the state of the object.

The work presents an analytical model for determining the onset of the disease using the TONTOR step model.

The proposed method provides the doctor with information, excluding the subjective factor, while the results of such information technology significantly increase the accuracy of determining the early stage of the disease. Purpose of work consists in modeling the diagnostic signs of appearance of multiple sclerosis at an early stage of development, and appearance of moment of action's onset of this pathology by analysis methods.

With this method of modeling, we have the opportunity to use affine and conformal transformations, which were considered earlier. In this case, the chord should be perceived as a directional vector with location accuracy. A circle is a consequence of an affine transformation. Thus, we have the opportunity to set the coordinates of the points of the trajectory and the circle in an unambiguous correspondence. In addition, since the real motion along the trajectory is characterized by oscillatory processes, the affine transformation of the model can be imagined as an exponential curve.

The proposed physical and mathematical information processing models will help determine the main points of creating the principles of operation of technical integrated diagnostic tools. The basis is a vector model for determining the state of biological objects, which will allow information signals to be determined with help of integrated TONTOR sensors and TONTOR step model.

As a result, the study of the nature of this functional dependence will provide analytical dependences in digital form, will allow the creation of a computer-integrated hardware solution that will eliminate subjectivity in diagnostics according to the "bad - good" principle.

Keywords: *TONTOR step; multiple sclerosis patients; positioning; spatial coordinates; information technology; diagnostics.*

Introduction

Treatment of multiple sclerosis as one of the common diseases is an urgent problem of modern world medicine. Most people with multiple sclerosis are diagnosed between the ages from 20 to 50, and women are two to three times more likely than men to be diagnosed with the disease. Multiple sclerosis affects more than 2.3 million people of working and reproductive age worldwide.

The disease has a negative prognosis, because it tends to progress and significantly reduce the human life quality: cognitive abilities and concentration of attention deteriorate; violations occur in the work of internal organs; there is muscle weakness, tremor of limbs.

Movement (pyramidal) disorders are characteristic of this disease. Of great importance is the syndrome of dissociation of the tendon-periosteal reflexes of the upper and lower limbs: increased knee

or Achilles reflexes with the expansion of reflexogenic zones while maintaining or reducing the reflexes of the upper limbs.

Currently, there are practically no technical means of full diagnosis of this disease, therefore, development of modern means of control is necessary, which provides wider opportunities for monitoring the patient's condition.

However, there are a number of problems, the main of which is the almost complete lack of physical, mathematical and hardware support for the diagnosis of this disease.

Significant progress in scientific research took place in 2015, when new ways to stop multiple sclerosis, restore function that has been lost, and treat the disease were proposed. National Society of Multiple Sclerosis [1], for its part, pursues all prospective solutions to uncover new medical and technical advances wherever such opportunities exist.

Here is a brief summary of the significant progress of modern research and initiatives of modern scientists, which confirms the urgency of the problem and the financial efforts of society aimed at creating new methods of diagnosis and treatment of multiple sclerosis. In addition, interest in the problem by the existence of the periodical publications "Journal of Multiple Sclerosis", "Multiple Sclerosis and Related Disorders" [2, 3, 4] etc. is confirmed.

For the most part, diagnosis is made based on indirect signs, i.e. history, subjective examination [4], however, recently, diagnostic methods using magnetic resonance imaging (MRI), cerebrospinal fluid (CSF) analysis, and visual evoked potentials (EP) have been introduced to speed up the diagnostic process, and there are some attempts to use blood test diagnostics. In work [6] such methods are considered: complex and nonlinear analysis, detrended fluctuation analysis, which can provide insight into changes in the condition of people with multiple sclerosis, i.e. identification of various signs of disease progression and related physiological function failures, which are manifested by changes in fluctuations within and between different time scales.

There are also research attempts [4, 5] method of confocal laser endomicroscopy for histological visualization of tissues in real time, and in particular for diagnosis of lesions of the brain and spinal cord. Research of optical coherence tomography have shown that the nerve fiber layer is different in people with multiple sclerosis than in healthy people, making this method a useful tool to learn more about optic nerve pathology and to collect additional evidence of disease activity when the diagnosis is suspected.

So, for comparison in work [5] evaluated the parameters of macula and retina of nerve fiber layer thickness using two different parameters of optical coherence tomography: the temporal domain and the spectral domain, in patients with multiple sclerosis and without unilateral optic neuritis, when it was possible to detect a difference in the data. There are also attempts to determine the signs of multiple sclerosis, using, for example, non-linear methods to identify adaptive and maladaptive dynamics of postural control in people with multiple sclerosis [6, 7].

However, despite a sufficient number of studies, it can be determined that there is still no method, let alone technical means, that allow a full-fledged diagnosis of whole system of body for the detection of multiple sclerosis, and therefore the proposed method is relevant.

That is, the diagnosis of multiple sclerosis is currently carried out, mainly, by separate devices with a difference in the diagnosis of the patient over time, which leads to errors in the identification of signals and the comparison of results [9, 10]. The diagnosis of multiple sclerosis remains mainly clinical, which requires "dispersion of symptoms in space and time." In the classic version, reliable multiple sclerosis is

characterized by the development of various manifestations in different periods of time. At the same time, a new aggravation may repeat the clinical picture of the previous one, but may occur with completely different symptoms [11, 12]. Therefore, it is necessary to constantly monitor the condition of the patient with detected signs of the disease.

Purpose of work consists in modeling the diagnostic signs of the appearance of multiple sclerosis at an early stage of development, and the appearance of moment of onset of the action of this pathology by hardware methods of analysis.

Physical and mathematical basis of TONTOR step

In author's works [13, 14, 15], the basis for distortions formation during the transition from imaginary to real space and conversely is considered, but it is necessary to pay attention to fact that these primary distortions of a straight line consist of a number of geometric constructions in space, as they have an effect on distortion of areas, volumes, and coordinate systems.

So, according to its construction, TONTOR step is a combination of a vector that draws an arc. In this case, the vector indicates the direction of movement, and the arc is the trajectory. In a simplified form, this situation is shown in work [14] (Figure 1). Function (1) in this case has sense of a vector. All other functions in this case play an imitation of real movement (2, 3, 4, 5).

Specificity of such movement is that the vector shows the direction of movement from one point to another, and its length is the distance between them. The vector acts as a function of the imaginary direction.

On other hand, the ends of the vector are combined by a real trajectory of movement. This trajectory can be significantly different from the targeted vector, because it can go around various obstacles. The beginning and end of this trajectory have coordinates that differ from the initial and final coordinates of the vector by value . In some cases, this value can reach the dimensions of duality.

In addition, it should be remembered that movement along trajectory is always directed in one direction. Thus, if we need to make a mathematical description of TONTOR step , we need to do it separately for the vector and separately for the trajectory as Figure 2.

Thus, in this given examples, it is clearly visible that the vector connects the points and at the time, when the real trajectory bypasses obstacles in way of movement.

The length that this object travels from start to finish is very important for TONTOR step. This length has three values, one according to the length of the vector AB (Figure 2,a), the second according to the real length and average.

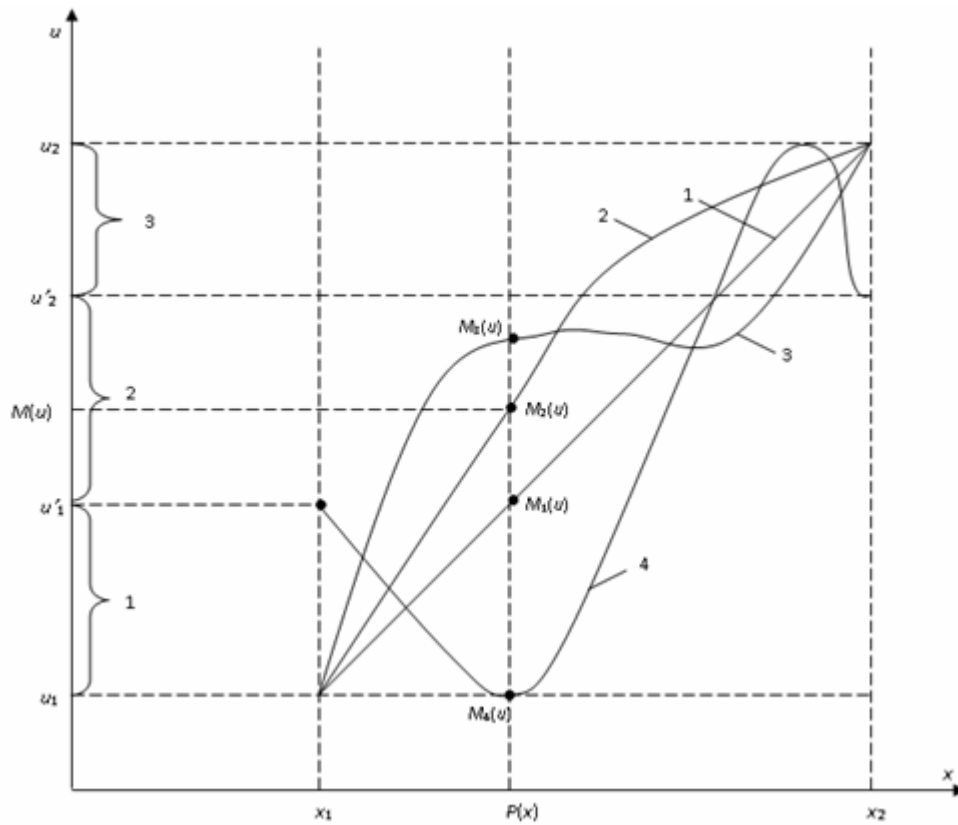


Fig. 1. Correspondence of points of intervals $[x_1, x_2]$ in the interval $[u_1, u_2]$ through the imaginary function [14]

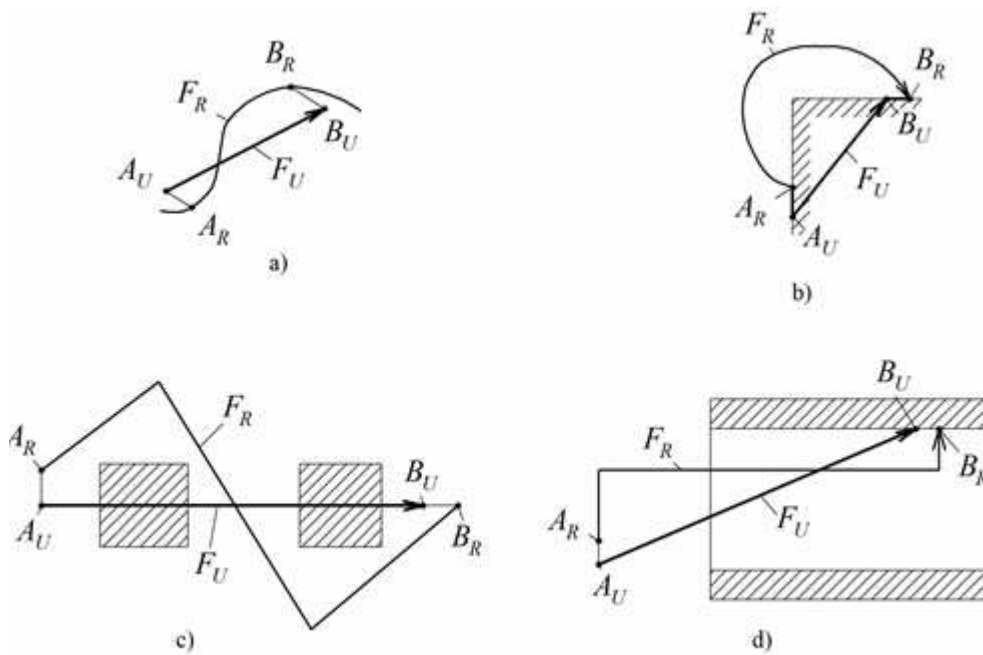


Fig. 2. General cases of TONTOR step: a) general case of TONTOR step; b) TONTOR step, when bypassing a right angle; c) TONTOR step, when overcoming a discrete obstacle; d) TONTOR step for internal movement

The second most important parameter is the speed of movement between extreme points. Such speed is imaginary by vector and real by trajectory. There is a parameter of efficiency of trajectory, that is, the ratio of imaginary to real path

In general, TONTOR step can be defined as a series of an infinite number of steps, i.e. for an imaginary step

$$[\bar{\mathbf{K}}]_U = [\bar{\mathbf{K}}]_1 + [\bar{\mathbf{K}}]_2 + \dots + [\bar{\mathbf{K}}]_n = \sum_{i=1}^n [\bar{\mathbf{K}}]_i$$

and for real

$$[\tilde{\mathbf{K}}]_R = [\tilde{\mathbf{K}}]_1 + [\tilde{\mathbf{K}}]_2 + \dots + [\tilde{\mathbf{K}}]_n = \sum_{i=1}^n [\tilde{\mathbf{K}}]_i.$$

At same time, each individual i -th step will be equal to the product of the speed by time interval, i.e.

$$[\mathbf{K}]_i = k_i V_p \Delta t_i,$$

where k_i is the speed coefficient;

V_p - maximum possible speed;

Δt_i - time interval for i -th step.

If we turn to general step, it is necessary to pay attention to fact that speed during its execution is not same in interval. That is, it depends on the coordinate and is a function of this distance $V_p = V_p(x)$. Similarly, we can state the fact that there is a function of time from the path $T = T(x)$.

As a result, we have speed and time in the following relationship

$$V_p = V_p \sum_{i=1}^n k_i = V_p \int_A^B k(x) dx$$

$$T = T(x) = \sum_{i=1}^n \Delta t_i = \int_A^B T(x) dx$$

So, as a result, the length of minimum step will be

$$[\tilde{\mathbf{K}}] = V_p \int_A^B T(x) k(x) dx \cdot dx$$

For a linear vector, this value will be determined as

$$[\bar{\mathbf{K}}]_{AB} = k_{AB} \cdot V_p \cdot t_{AB}. \quad (1)$$

Since there is a TONTOR step, there is also a minimum displacement (1) for which this step can be registered. According to [14, 15], the minimum length of the line that turns into a hyphen is the distance in $3[\mathbf{S}]$. As a result, the length of the trajectory is also determined in $3[\mathbf{S}]$, since a smaller length loses any meaning. The start and end of the trajectory step have an uncertainty within $[\mathbf{S}]$ (Figure 3).

Since the total length of the trajectory, as a parameter, has the following dependence

$$[\tilde{\mathbf{K}}] + [\bar{\mathbf{K}}] = V_p \int_A^B T(x) k(x) dx + k_{AB} \cdot V_p \cdot t_{AB},$$

then the limit value of step function will be determined as

$$\lim([\tilde{\mathbf{K}}] + [\bar{\mathbf{K}}]) = 8[\mathbf{S}].$$

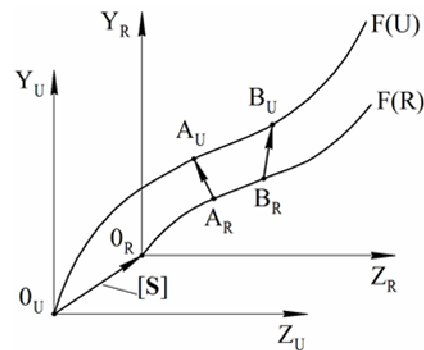


Fig. 3. A general case of TONTOR step in the transformation of imaginary - real components of movement

Currently, we have the opportunity to observe such a situation in the picture (Fig. 4).

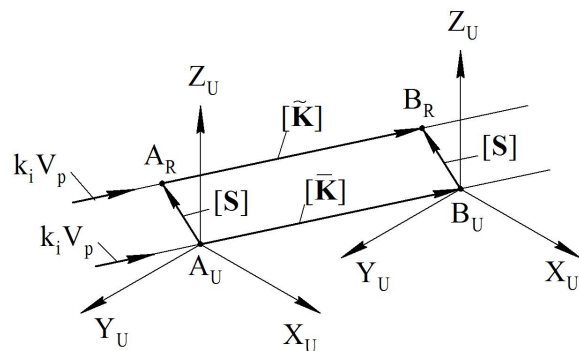


Fig. 4. Graphical interpretation of minimum TONTOR step

At the same time, the movement distances are equal to following values:

$A_U B_U = 3[\mathbf{S}]$ - imaginary direction vector;

$A_R B_R = 3[\mathbf{S}]$ - vector of real motion;

$A_U A_R = [\mathbf{S}]$ - uncertainty vector of point coordinate;

$B_U B_R = [\mathbf{S}]$ - uncertainty vector of point coordinate.

In this situation, the imaginary vector is equal to the value of real path. Purely from a principled point of view, such equality has minimum size requirements, although in general it can be infinity, because vector imposes only the coordinates of beginning and end of step and not its length.

So, as a result, there is a quality of TONTOR step performance, this is the ratio of vector length to the real path length

$$\xi = \frac{[\tilde{\mathbf{K}}]}{[\mathbf{K}]} \quad (2)$$

The limit of this value corresponding to conditions (5, 6) at author work [14].

In a simplified form, TONTOR step ring takes the form

$$[\mathbf{K}] = \oint_{[\tilde{\mathbf{K}}]} f(x, y, z) dl + [\tilde{\mathbf{K}}] \quad (3)$$

It can be seen from equation (2) that there is a situation, when the curvilinear integral can be equal to zero, i.e. from equation (3) the following follows

$$\oint_{[\tilde{\mathbf{K}}]} f(x, y, z) dl = [\tilde{\mathbf{K}}] = 3[\mathbf{S}] \quad (4)$$

Thus, our studies of TONTOR step are reduced to the determination of two quantities, namely the linear direction vector and the curvilinear trajectory of the object's movement.

Analysis of imagine and real trajectories of TONTOR step

The main study of TONTOR step is a comparative analysis of ratio of the direct action vector $[\mathbf{K}]$ and real trajectory $[\tilde{\mathbf{K}}]$, which provides the possibility of diagnosing a violation of trajectory of human movement. It was previously shown that there is a coefficient of step realization (2). But this is not only parameter of TONTOR step. Therefore, to begin with, we will consider whole range of possible step parameters.

First, it is an imaginary (phantom) vector of the movement direction and its length, i.e. $[\tilde{\mathbf{K}}]$.

Secondly, the length of the vector in space is determined by the coordinates of its beginning and end. For this, the coordinates must be determined with maximum accuracy, i.e. no worse than $[\mathbf{S}]$.

Thirdly, the trajectory of the real movement, as a phantom image of the movement function, and the method of its implementation should be determined.

So, we previously considered the physical and mathematical models of phantom rectilinear vectors and curvilinear trajectories of movement between two points. Despite a rather simplified consideration, we got a rather complicated situation with the description of the movement during the TONTOR step. But there are quite a large number of options for performing the steps and, as a result, for their mathematical description. It is enough to consider a fairly simple situation, when it is necessary to bypass an ordinary rectangular obstacle Figure 5. At the same time, it is necessary to reproduce step from point A to point B .

As a result, we have the opportunity to go around the object along a curvilinear trajectory or along a broken line (T_p). It is quite clear that for any trajectory

there will be a requirement for minimum energy expenditure at maximum speed. Therefore, optimality of these parameters will be determined by the minimum length of the path.

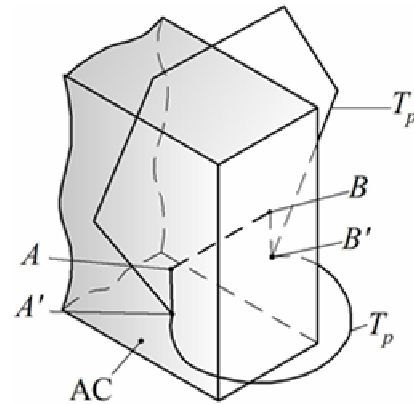


Fig. 5. Simplest version of TONTOR step

Accuracy of output to vector coordinate A or B is determined by the speed of movement along the trajectory $K_i V_p$. During acceleration and deceleration, we get the corresponding coordinate determination errors such as AA' , BB' , which should not exceed the value of $[\mathbf{S}]$. In the case of optimality of step parameters, there is always a plane on which the vector \overline{AB} , error vector $\overline{AA'}$, $\overline{BB'}$ and corresponding trajectory can be located. At same time, the minimum length of the trajectory will be located on the object's surface.

Let us consider possible cases of such trajectories on basis of conducted research. So, let's start with the elementary limiting case and minimum contour of TONTOR step, i.e. (3) and (4). In this case, we have length of the direction vector $[\tilde{\mathbf{K}}] = 3[\mathbf{S}]$. This vector cannot be smaller than $3[\mathbf{S}]$, because with existing quantization step, next value is $2[\mathbf{S}]$. But for such a magnitude of vector, coordinate points are extremely ill-defined because the coordinates go from the concept of "point" in the imaginary system (A and B) to a real "point" (A' and B'). In addition, the coordinates of beginning and end of vector are determined with an accuracy no better than $[\mathbf{S}]$. In this case, the aperture of direction vector can reach 120° . Consideration of this situation leads to conclusion that the geometry of complete trajectory $[\mathbf{K}]$ is a rectangle with a perimeter of $8[\mathbf{S}]$. Currently, long sides of the figure have a length of $[\tilde{\mathbf{K}}] = 3[\mathbf{S}]$ and $[\tilde{\mathbf{K}}] = 3[\mathbf{S}]$, and short sides of $[\mathbf{S}]$. The location of direction vector and its corresponding motion trajectory is indeterminate in the space occupied by volume of idealized line as a geometric figure. The direction of these microvectors depends on the direction of external force (principle of small

displacements). But at same time, within limits of this figure, the rectangle will be distorted into a flat parallelogram. A different situation will be observed when the magnitude of the movement trajectory increases. In this case, at some point it will become parabolic, as in the case in work [15] and at Figure 5 as shown. It should be noted that the values $[\bar{\mathbf{K}}]$ and $[\tilde{\mathbf{K}}]$ are slightly different in size and, as a rule, are in the same plane.

That is, on this example, we should observe one of TONTOR step properties, namely, the possibility of scaling. Value $[\mathbf{S}]$ is an extraneous factor in the accuracy of determining the coordinates, depending on the relative speed of the objects to each other and the measurement time of staying within the determined coordinates. The speed of relative motion refers to the speed relative to which an object comes and goes from a point A and to B . As a result, we get the points A' and B' . In addition, this value depends on time of measurement of moment passing through the coordinate.

Most often, the principle of stepping is inherent in biological objects. Of course, in first place of this phenomenon is the biological object's movement, which is accompanied by stepping. At same time, the steps have a dual character, it is enough to remember how a person steps or moves some objects. Such TONTOR steps (cycles) are observed everywhere and many examples can be given. According to this principle, they form stepping chains.

The conclusion from all of the above may be possibility of creating a model of abstract TONTOR step. In this case, we have four sections that create a TONTOR step. Let's consider these components according to their degrees of importance. The first component of vector chain of TONTOR step is the phantom vector $[\mathbf{S}]$ at the beginning of movement (point A). A similar phantom vector exists at end of the movement (point B). Between points A' and B' is our basic direction vector $[\bar{\mathbf{K}}]$, i.e. \overline{AB} .

Encloses the entire contour of this trajectory, which can be defined as a series of vectors of small size, which under a certain approximation ($[\mathbf{S}]$) has the form of a spatial curve $[\tilde{\mathbf{K}}]$. Each of these elements can be considered as a small TONTOR step, the general appearance and theory of which is shown in [15]. If we discard all secondary features, then we get a regular contour that can be considered as a regular circle and a chord that cuts off a certain shade of the circle. With this method of modeling, we have the opportunity to use affine and conformal transformations, which were considered earlier. In this case, the chord should be perceived as a directional vector with location accuracy ($[\mathbf{S}]$). A circle is a consequence of an affine transformation.

Thus, we have the opportunity to set the coordinates of the points of the trajectory and the circle in an unambiguous correspondence. In addition, since the real motion along the trajectory is characterized by oscillatory processes, the affine transformation of the model can be imagined as an exponential curve.

Conclusions

The work analyzes the existing methods of diagnosing multiple sclerosis, which are currently used by modern medicine. For the most part, all these works have the character of developing more theoretical principles of diagnosis based on rather indirect signs and do not provide a complete picture at the early stage of the development of this disease. Therefore, the purpose of this work is defined as the creation of models for early diagnosis of multiple sclerosis based on the determination of the patient's motor actions, which are responsible for his general condition.

The proposed physico-mathematical models of information processing will help determine the main points of creating the principles of functioning of technical integrated diagnostics. It is based on a vector model for determining the state of biological objects, which will allow determining information signals using built-in TONTOR sensors and the TONTOR step model.

At the same time, the models involve comparing the idealized parameters of the vector fields with the real current characteristics of the object under study and determining the difference as a differential function that corresponds to the diagnostic parameters of the state of the object in patients with multiple sclerosis.

As a result, the study of the nature of this functional dependence will ensure obtaining analytical dependencies in a digital form, will allow to create a computer-integrated hardware solution that will eliminate subjectivity in diagnostics according to the "bad - good" principle.

At the same time, the application of the proposed method in medical practice will allow preventive actions during general examinations and prevent serious consequences of this disease.

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ВИЗНАЧЕННЯ ДІАГНОСТИЧНИХ ОЗНАК РОЗСІЯНОГО СКЛЕРОЗУ ЗА ДОПОМОГОЮ МОДЕЛІ КРОКУ ТОНТОР

В роботі проведений аналіз існуючих методів діагностування розсіяного склерозу, що наразі застосовує сучасна медицина. Здебільшого всі ці роботи мають характер розроблення більш теоретичних принципів діагностики на основі досить опосередкованих ознак та не надають отримання повної картини на ранній стадії розвитку цього захворювання. Втім саме ця рання стадія цього захворювання може ще піддаватись лікувальному впливу та запобіганню розвитку важких наслідків. Тому мету цієї роботи визначено як створення моделей ранньої діагностики розсіяного склерозу на основі визначення рухових дій пацієнта, що відповідає за його загальний стан.

Проведені теоретичні дослідження дають базові тези щодо створення узагальненої концепції діагностики ознак розсіяного склерозу, яка має визначити параметри спотворення ідеалізованої моделі системи організму реальним характером захворювання та плинним станом об'єкта.

У роботі представлено аналітичну модель для визначення початку захворювання за ступінчастою моделлю ТОНТОР.

Запропонований метод надає лікарю інформацію, що виключає суб'єктивний фактор, а результати такої інформаційної технології значно підвищують точність визначення ранньої стадії захворювання.

Мета роботи полягає в моделюванні методами аналізу діагностичних ознак появи розсіяного склерозу на ранній стадії розвитку та виявленні моменту настання цієї патології.

Застосовуючи ці методи моделювання, ми маємо можливість використовувати афінні та конформні перетворення, які були розглянуті раніше. У цьому випадку хорду слід сприймати як спрямований вектор з точністю розташування, а коло є наслідком афінного перетворення. Таким чином, ми маємо можливість встановити координати точок траєкторії та кола в однозначну відповідність. Крім того, оскільки реальний рух за траєкторією характеризується коливальними процесами, афінне перетворення моделі можна уявити у вигляді експоненціальної кривої.

Запропоновані фізико-математичні моделі обробки інформації допоможуть визначити основні моменти створення принципів функціонування засобів технічної інтегрованої діагностики.

В основу запропонованого методу ранньої діагностики розсіяного склерозу як навіть незначних впливів на руховий апарат людини покладено векторну модель визначення стану біологічних об'єктів, яка дозволить визначати інформаційні сигнали за допомогою вбудованих сенсорів ТОНТОР та ступінчастої моделі кроку ТОНТОР.

Як наслідок, дослідження природи цієї функціональної залежності забезпечить отримання аналітичних залежностей у цифровій формі, дозволить створити комп'ютерно-інтегроване апаратне рішення, яке усуне суб'єктивність у діагностиці за принципом «погано – добре».

Водночас, застосування запропонованого методу в медичній практиці дозволить здійснювати профілактичні дії при загальних профілактичних обстеженнях та запобігати важким наслідкам цього захворювання.

Ключові слова: крок ТОНТОР; хворі на розсіяний склероз; просторові координати; інформаційні технології; діагностика.

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