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Diagnosis of neuro-physiological state of a person on the biomechanical parameters

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Abstract

In this paper described the algorithm for registering the spatial parameters of the locomotors apparatus of man based on the accelerometric goniometry method and the subsequent transformation of acceleration signals in the angular settings through specialized algorithms and phase-measurement method. Revealed correlations in the system of "musculoskeletal system - the nervous system." Based on the established relationship of the dynamic activity of neurons in the brain and the implementation of motor actions, it was identified the main informative neurophysiological parameters, largely responsible for motor function.

Algorithms synchronous processing of the patient's measured dynamic parameters in real time. In the process of registering the parameters proposed to build a dynamic model of the patient and to carry out its correction with the expansion of the database of measurement. The resulting model, after processing of the neural network will be entered into the database models, creating statistics and providing a choice of optimal system performance parameters for a particular patient. With the help of neural network algorithms and decision support system based on a database of goniometric measurements, DB evoked potentials of brain and the database of diseases, determined an approximate diagnosis of the patient.

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Keywords: biomechanics; information system; goniometric control; accelerometer; mathematical model.

1. Introduction

Diagnostics of the locomotor apparatus of man is a complex and multi-criteria process, depending on the quality and accuracy is determined by the course of the rehabilitation of the patient and provides a timely warning of skeletal abnormalities, indirectly affecting the quality of the functioning of many internal organs. The diagnosable key parameters are kinematic performance elements of the skeletal system, the control of which is a classical problem of medical goniometer. The solution to this problem is solved by means of goniometric systems detected slope parameters and relative movement between the vertebrae and the elements of the joint connections, determine the scope and range of motion of parts of the locomotor apparatus of the patient[1].

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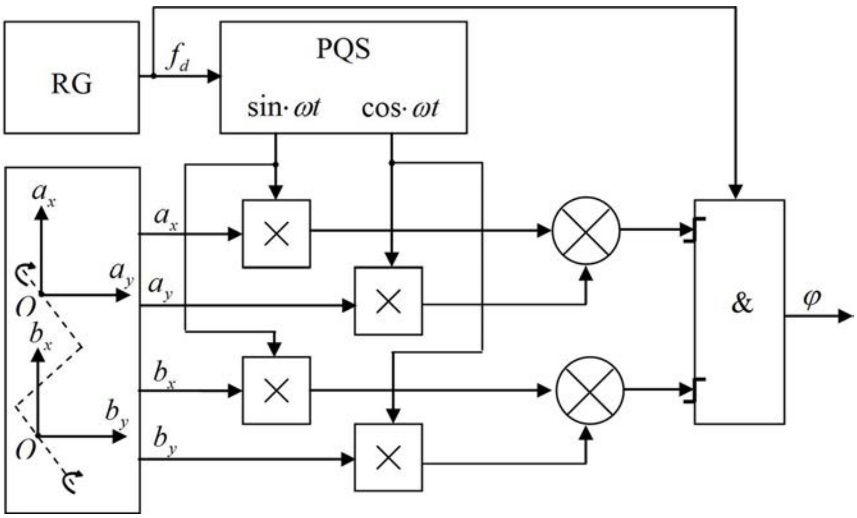

Fig. 1. The algorithm of collection and pre-processing of goniometric control data

However, taking into account only the angular motion parameters is not enough to get the full information of the dynamic picture of the motion, because the process of the total motion of the elements of human skeletal system consists of a considerable variety of motor reactions, characterized by developing a force, speed, complexity of trajectories involving the muscles of the limbs and trunk links. Consequently, when organization of human biomechanics goniometric monitoring, acquires great importance the study of the central control mechanisms targeted physical activity[2,3].

2. The algorithm of collection and pre-processing data of goniometric control

As a basis for constructing a system of registration of kinematic parameters of the locomotor apparatus of man with a high degree of accuracy it is proposed to use the accelerometer transducers which exhibit optimum normalized metrological characteristics, high accuracy, sensitivity and small dimensions and can be easily integrated into the control system goniometric.

Implementation the accelerometric method of rotation angle measuring in the goniometric control systems, is based on a certain algorithm collecting dynamic data, which is based on the direct conversion of signals from two-component accelerometers in phase sine wave by multiplying the signal on the phase quadrature signals (PQS) with a frequency which is a multiple of the reference oscillator frequency[4] (RG) (Figure 1).

The signals from the accelerometer will have a harmonic component:

$$U_{y1} = a_y \cdot U_{\sin}\omega t; U_{x1} = a_x \cdot U_{\cos}\omega t; \tag{1}$$

$$U_{y2} = b_x \cdot U_{\sin}\omega t; U_{x2} = b_y \cdot U_{\cos}\omega t; \tag{2}$$

According to this algorithm, the angle of rotation bio kinematic couples in the accelerometric goniometer is determined by the phase difference between the measured and the reference signal phase[5]. Therefore, by summing the received harmonic signal is generated at the output a signal proportional to the angle of bio-kinematic pairs without affecting instability coefficients transmitter branches:

$$\sum U_1 = U_{x1} + U_{y1} = U \cdot \left(\sqrt{a_y^2 + a_x^2} \cdot \sin(\omega t + \varphi) \right) \tag{3}$$

$$\sum U_2 = U_{x2} + U_{y2} = U \cdot \left(\sqrt{b_y^2 + b_x^2} \cdot \sin(\omega t + \varphi) \right) \tag{4}$$

where φ- phase signal, proportional to the angle of rotation of the links relative to each other.

Further, the result of the phase detecting, signal takes the form:

$$S = \sum U_1 \cdot \sum U_2 = \frac{1}{2}(\cos\varphi - \cos(2\omega t + \varphi)) \cdot U^2 \cdot \sqrt{a_y^2 + a_x^2} \cdot \sqrt{b_y^2 + b_x^2} \quad (5)$$

After low-pass filtering obtain expression from which can be easily computed phase signal:

$$S_f = \frac{1}{2} \cdot U^2 \cdot \sqrt{a_y^2 + a_x^2 \cdot b_y^2 + b_x^2} \cdot \cos\varphi \quad (6)$$

3. A dynamic model of the physiological characteristics of human

As noted earlier, to obtain a complex pattern of motor pathology is not enough to control only skeletal kinematic parameters. In addition to high-precision goniometric measurements, necessary to record the parameters of the brain and neuromuscular activity of the person in the process of movement.

It is found that the dynamic activity of brain neurons, relating to the implementation of tool movements typically starts 50-150 ms. prior to the occurrence of EMG activity and ended after a traffic stop. Thus, the joint reaches equilibrium during the dynamic development of the motor cortex neuronal activity phase, long before the establishment of steady equilibrium level of neural activity. The maximum value of the mean frequency of neural activity in one bin of duration 50 ms, in dynamic phase reactions neurons did not correlate with the magnitude of the equilibrium steady-articular angle (Fig. 2). At the same time, a positive correlation was found between the average frequency of neural activity in the whole dynamic phase and magnitude response of articular angle achieved[6,7].

The results presented show that the maximum level of motor neuron activity depended primarily on the joint movement velocity and the duration of this movement. Thus, the data obtained contribute to defining the criteria of permissible values characterizing parameter limit patient physiological parameters in the norm, which can be determined by the degree of deviation and pathological conditions. On the basis of these data, it was identified informative parameters and their correlations in the system of "musculoskeletal system - the neuromuscular system" man. Neurophysiological criteria are also formed based on statistical clinical studies of patients under normal conditions and in the presence of deviations.

4. The choice of informative variables for constructing diagnostic models

The primary step in the task of building a diagnostic model of the health status of the patient is a collection of informative variables.

Based on the collected informative variables generated data sample. To the sample data can be built with a maximum adequacy to the real object, the data sample should be representative, ie fully and adequately display the diagnostic object. The representativeness of the sample can only be achieved by selecting data objectivity (Fig. 3)

It is proposed to implement the correction of the dynamic model of the patient with the basis for measurement, and based on the obtained dynamic model of the patient, will be formed an information model. Information model, after the processing of the neural network will be entered in the database of models, thus, will be formed a statistics and selected the optimal operating parameters of the system rehabilitation for patients with a variety of neurophysiological features. According to the physiological parameters model of the patient, will be determined by the maximum pain thresholds and minimum thresholds of sensitivity upon the rehabilitation of the musculoskeletal system. With the help of neural network algorithms and algorithms for systems of decision support (DSS) based on database of the measurements, the database of the evoked potentials and the diseases database, determined an approximate diagnosis of the patient. Neurophysiological criteria are also formed based on statistical clinical studies of patients under normal conditions and in the presence of deviations.

The sample data is represented as a matrix whose dimension $N \times (n + 1)$:

$$W_N = [X_n | Y_m] \quad (7)$$

where N - number of cases (rows in the matrix); n - number of informative input variables; m - number of informative output variables; $X_n\{X_1, X_2, ..., X_i, ..., X_n\}$, $Y_m\{Y_1, Y_2, ..., Y_j, ..., Y_m\}$ - the set of vectors of values of input and output

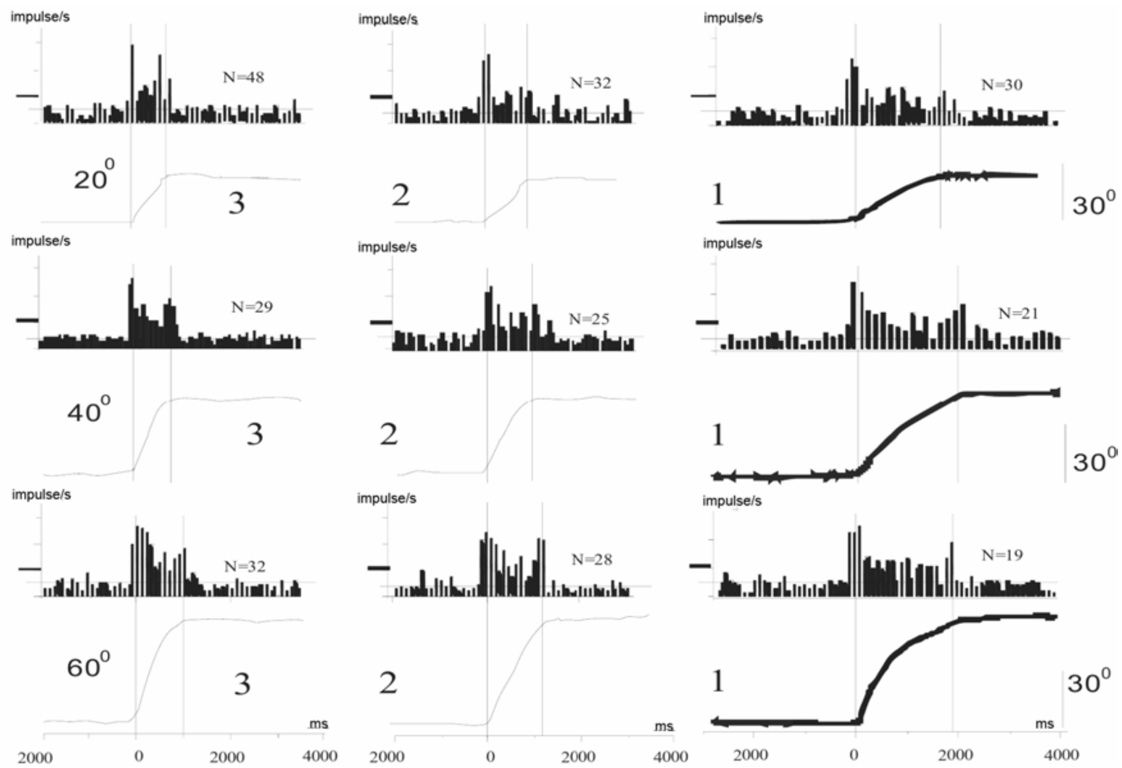

Fig. 2. The activity of neurons of the motor cortex and changes in the articular angle, when the flexion movement at different joint velocity. Legend: 30Âž, 40Âž, 60Âž - changes in the articular angle. Ordinate - average frequency of pulses in the bin. The line parallel to the x-axis indicates the average frequency of the background activity of the neuron. Vertical lines indicate the boundaries of dynamic and stationary phases of motion. 1,2,3 - joint flexion speed, N- number of iterations

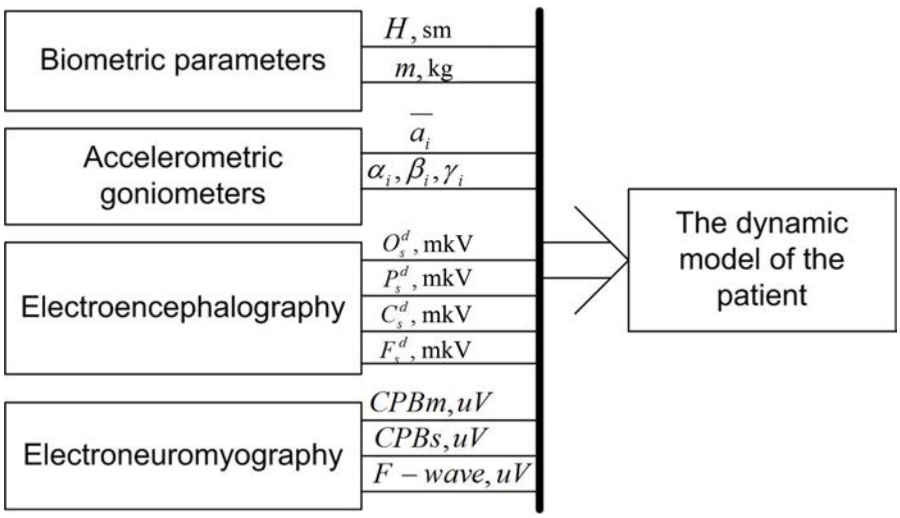

Fig. 3. The dynamic model of the patient's physiological parameters

variables as well $X_i\{x_{i,1}, x_{i,2}, ..., x_{i,N}\}$, $Y_i\{y_{j,1}, y_{j,2}, ..., y_{j,n}\}$: $x_{i,N}$, $y_{j,N}$ -i-th value of the input and the j - th informative value of the output variable of N - line data sample matrix.

Each data line contains sample values of the input (information on chronic diseases, data from patient history) and output (current symptoms, the results of goniometry (accelerometry)) informative variables pointing to the dynamic state of a particular patient. Sampling should include a training data sample, which is used at the stage of building a model to the real diagnosis object. An important condition for the use of samples is that the data stored in the learning sample data and control, must be different. This ensures reliability of the diagnostic decisions.

As a rule, the quality of the data sample, spine diagnostic systems involved in learning, evaluated on the following criteria: representativeness, representativeness, informativeness, and reliability.

To determine the degree of connection between the informative variables, i.e., to assess the informative sample data, are used rank correlation. The relationship between signs (on a Cheddok scale) may be strong, moderate and weak. Closeness of the relationship is determined by the magnitude of the correlation coefficient, which can range from −1 to +1 inclusive[8].

To calculate the required sample size is suggested to use the following formula:

$$N = n_{inf} \cdot (P \cdot \alpha / \eta^2), \quad (8)$$

where n_{inf}- number of informative variables, P - the representativeness of the sample data;α - the required representativeness of the sample data;η-getting the information content of the sample data.

The training set of data is consists of training and control samples having the ratio of 2:1 and separable randomly.

Using the accelerometer measurement method as a basis for building the automated system of goniometric spine control used to optimize of medical biomechanical research requires immediate accounting of assigned statistical range of physiological fluctuations to parameters of bio kinematic norm and degrees of functional disorders of the spine (Table 1). Formation of informative variables for the construction of multi-level diagnostic model based on the medical reference books, which reflect the dependence of the manifestations of a disease from the current symptoms and reported violations[9].

5. Conclusion

Given that the main parameter characterizing the accuracy of modern goniometric systems is the adaptability of the mathematical model, the ability to adjust the hardware and instrumental errors of the system, the article provides for the use of adaptive dynamic model based on specialized algorithms for signal processing. This model eliminates the algorithmic error of the accelerometric method, due to the need to calculate the arc tangent in the transformation of acceleration value obtained from the accelerometers in the angular value by eliminating the division operation. It should be noted that the described algorithm collecting and preprocessing data goniometric control uses a linear approximation, whereby informative signal linearization is achieved, which allows to obtain the required accuracy.

Acknowledgments

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