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IMPLEMENTATION OF DECISION-MAKING SYSTEMS BASED ON A TYPICAL DECISIVE ELEMENT

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Abstract. As large amounts of data are received and accumulated, the need to create automated and automatic decision-making systems for a wide variety of tasks becomes more and more urgent. In the technical field, one of them is technical diagnostics, and in medicine, diagnostics of the human condition. Currently, dozens of computer systems for continuous vibration control and monitoring of complex rotary-type units are in commercial operation, which form time trends for 14 vibration parameters with a time step of 1–8 s for each control point at the operated facility. The functionality of a universal decision-making module is proposed, the input data of which are the parameters and characteristics of the observed object, with the required resulting output decision.

Keywords: parameter, characteristic, solution, vibration, signal, digital processing, amplitude spectrum.

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РЕАЛИЗАЦИЯ СИСТЕМ ПРИНЯТИЯ РЕШЕНИЙ НА БАЗЕ ТИПОВОГО РЕШАЮЩЕГО ЭЛЕМЕНТА

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Аннотация. По мере получения и накопления больших объемов данных все более актуальной становится необходимость создания автоматизированных и автоматических систем принятия решений для самых разнообразных задач. В технической сфере одной из них является техническая диагностика, а в медицине – диагностика состояния человека. В настоящее время в промышленной эксплуатации находятся десятки компьютерных систем непрерывного контроля вибрации и мониторинга сложных узлов роторного типа, которые формируют временные тренды по 14 параметрам вибрации с шагом по времени 1–8 с для каждой контрольной точки на эксплуатируемый объект. Предложен функционал универсального модуля принятия решений, входными данными которого являются параметры и характеристики наблюдаемого объекта, с требуемым результирующим выходным решением.

Ключевые слова: параметр, характеристика, решение, вибрация, сигнал, цифровая обработка, амплитудный спектр.

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Introduction

In production processes, a significant part of the operating costs are the costs allocated to ensure the operability of production equipment. It is believed that the equipment with rotational motion is the most worn out (turbines, generators, engines, gearboxes, pumps, compressors, fans). It is possible to reduce the cost of its operation by introducing modern maintenance systems based on the use of technologies for monitoring, assessing the state, diagnosing, predicting the development of defects, which, from the point of view of their organization and functioning, are intelligent systems [1].

The state of production equipment can be characterized by many parameters of the main and secondary processes that develop during its operation. For control, it is advisable to choose those that reflect the functional state of objects quite well and do not require too much expenditure for their measurement. In this regard, for mechanisms with rotational motion, these are the vibration parameters [1, 2]. Based on the analysis of the vibrational state of a group of the same type of mechanisms during their operation in different modes, in different technical conditions and for a long time, diagnostic signs can be substantiated and formulated to localize the places and causes of increased vibration. This creates the conditions for building automated or automatic systems for assessing the technical condition and diagnostics, which greatly facilitate the work of engineering and technical personnel [3].

Medical diagnostics, as a set of rules, methods and solutions that allow one to come to a conclusion about the presence or probability of a person having a particular disease, has much in common with technical diagnostics [4]. The discovery of new and improvement of existing methods for assessing the human condition is an important area of medical research. In this regard, the formalization of decision-making systems based on the data obtained is very relevant, and more and more accessible for creation, at least for many special cases, due to the growing computing and information power of the technical means used.

Model of the basic element of the decision-making system

Currently, there is a need to monitor the state of not only technical objects, but also living organisms, including humans. The state of the observed technical or natural object is described by parameters and characteristics. In this article, these terms and characteristics will correspond to the following definitions.

A parameter is a property (indicator) of an object or system that can be measured. The result of measuring a system parameter is a number or quantity, and the system itself can be considered as a set of parameters that need to be measured in order to model or evaluate its behavior. Sometimes parameters are also called quantities that change very slowly compared to other quantities (variables). Examples of vibration parameters are: root mean square value (RMS) of vibration acceleration (vibration velocity), amplitude of vibrations, amplitude of vibrations at a certain frequency, calculated by processing the vibration signal generated by primary transducers (sensors) mounted on the bearing support of the mechanism.

A characteristic is a set of distinctive properties of someone or something. A characteristic in engineering is a graphic or tabular expression of the dependence of one parameter on another, as well as a function that expresses or describes this dependence. For example, a characteristic of an object is the amplitude spectrum of the vibration signal excited on the housing of the bearing support or the segment of the temporal realization of the vibration signal.

In order to evaluate the state of the observed object, some kind of decision-making or decision support system is required. The following model of the basic decisive element of the decision-making system for assessing the state of the observed object or developing recommendations for the impact on this object is proposed. The base element inputs are: x_i − parameter value *i*; $i = 1...N$; $\omega_j\left(y_{j,1},.....,y_{j,k}\right)$ – characteristic *j* at discrete values of the argument y_j; $j = 1...M$; $\omega_j\left(y_j\left(t\right)\right)$ – characteristic *j* at a continuous value of the argument y_j, $j = 1...M$.

In relation to the input initial parameters and characteristics, the following primary processing functions are applied: $f_l\left(x_i\right)$, where $l = 1...B$; and $\varphi_m\left(\omega_j\right)$, where $m = 1...C$.

Moreover, different functions f_l can be applied in relation to the same parameter x_i, and different functions φ_m, to the same value of the characteristic ω_j. There can also be complex multi-parameter-multi-characteristic functions: $\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right)$, where $n=1...D$; $i,j,k\in 1...N$; $l,m,p\in 1...M$.

In relation to the feature set: $f_l\left(x_i\right)$, $\varphi_m\left(\omega_j\right)$, $\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right)$ generalizing functions are applied: $y_k=\Psi_k\left[f_l\left(x_i\right), l=1...B;\ \phi_m\left(\omega_j\right),\ m=1...C;\ \psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right),\ n=1...D\right]$; $k=1...L$. And already in relation to y_k apply various decisive functions: $S_\eta\left(y_k\right)$, $\eta=1...P$.

The result of the function $S_\eta\left(y_k\right)$ determines one of the possible states of the analyzed object, the type of the object itself, and the decision to be made. In Fig. 1, this model is presented graphically.

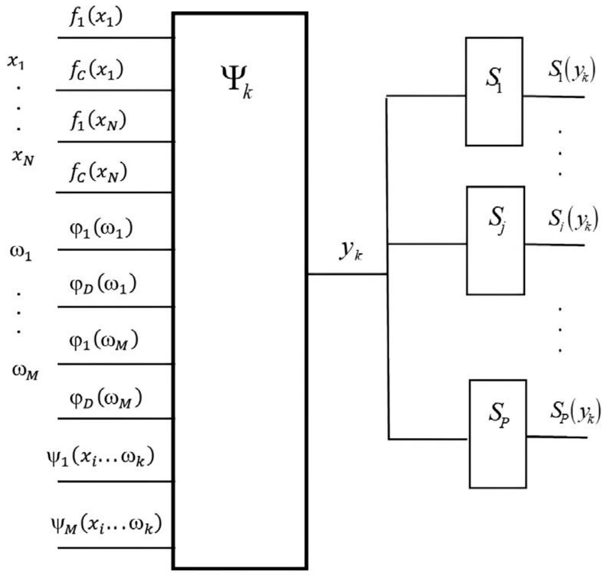

Fig. 1. Model of the basic decision-making element for assessing the state of the observed object

In the simplest case, the parameters of the proposed decision-making model will have the following form:

$$f_l\left(x_i\right)=a_l x_i,\ \text{where}\ l=1...B;\ \varphi_m\left(\omega_j\right)=b_m\omega_j,$$

where $m=1...C$; a_l, b_m – real numbers;

$$\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right)=c_n\left(\sum_{i=1}^{N}r_i x_i+\sum_{j=1}^{N}s_j\omega_j\right),$$

where $n=1...D$; $i,j,k\in 1...N$; $l,m,p\in 1...M$; r_i, s_j – real numbers.

$$y_k=\sum_{l=1}^{B}u_{l,k}f_l\left(x_i\right)+\sum_{m=1}^{C}\nu_{m,k}\phi_m\left(\omega_j\right)+\sum_{n=1}^{D}w_{n,k}\psi_n\left(x_i,..,x_j,..,x_k,\omega_l,..,\omega_m,..,\omega_p\right),$$

where $k=1...L$; $u_{l,k}$, $v_{m,k}$, $w_{n,k}$ – real numbers.

$$S_\eta\left(y_k\right)=\rho_\eta y_k,\ \eta=1...P.$$

The fundamental difference between the proposed basic element of decision-making about the state of an observed object, event, action, for example, from a neural network [5] is that it provides functional variability in the primary processing of the obtained parameters and characteristics, as well as the possibility of making decisions as a result of observing an object on over some time interval. The typification of the decisive element makes it possible to configure complex decision-making networks on their basis and create intelligent systems for processing various data.

Application of basic element of the decision-making system in automatic protective shutdown of a turbine unit based on vibration parameters

The most important task of modern vibration control and diagnostic systems is to prevent accidental damage to the protected object in the event of a sudden malfunction or mechanical damage in its components, or in the event of a significant deviation of any technological parameters from the nominal ones. However, the fact of the occurrence of a situation requiring the shutdown of a technical object in many cases has an ambiguous reflection in the vibration parameters. The standardized protection criteria [6] reflect the most general relationships obtained on the basis of long-term operating experience and research of mechanisms with rotational motion, and by no means always fully satisfy the operating and management personnel.

Vibration control and protection systems built on the basis of computer technology make it possible to implement various and complex protection algorithms focused on specific types of defects and emergencies. This, in turn, makes it possible to avoid unreasonable ("false alarm") trips of the protective shutdown and prevent "missing a defect" [7, 8]. Implemented and tested on a number of turbine units is an algorithm for protective shutdown by vibration, which takes into account several factors.

1. Factor of the low-frequency component of the vibration

Under the low-frequency vibration (LFV) is understood the mean square value of the vibration velocity (RMS) in the frequency zone equal to half the reverse. A protective shutdown signal is generated if the following situation occurs for any bearing support of the turbine set: RMS vibration velocity LFV, measured for the vertical direction and for the transverse-horizontal direction of any bearing support, exceeds *v* mm/s for 4–6 s and, at the same time, for at least one of these directions, it exceeds 3*v* mm/s during the same time. The level *v* is determined by the type and operating frequencies of the movement.

2. The factor of the reverse component of vibration

The reverse component of vibration is understood as the RMS of the vibration velocity of the spectral component with a frequency equal to the frequency of rotation of the shaft (rotor) of the unit.

2.1. The value of the RMS of the turnover component

For each bearing support and each of the directions of vibration measurement, the RMS value of the vibration velocity of the reverse component is set, corresponding to the emergency level, which is selected taking into account the design, functional and operational features of the controlled mechanism. A protective shutdown signal is generated if, at four or more control points, the RMS of the vibration velocity of the reverse component exceeded the emergency level specified for the corresponding point.

2.2. Increment vector of the turnover component

For each bearing support and each of the vibration measurement directions, the value of the turnover component increment vector is set, corresponding to the emergency level. A protective shutdown signal is generated if at four or more measurement points the turnover component increment vector has exceeded the emergency level specified for the corresponding measurement point.

3. The factor of the high-frequency component of the vibration

The high-frequency component of vibration (HFV) is understood as the RMS vibration velocity in the frequency band, the lower limit of which is equal to the double reverse frequency, and the upper limit is the upper limit of the frequency range in which the vibration control of the observed mechanism is performed. A protective shutdown signal is generated if, for any two directions of vibration measurement for any bearing support, high-frequency vibration exceeded the alarm level set for this object for 3–6 s.

The signal for the protective shutdown of the controlled mechanism is generated if it is generated according to one of the specified criteria, or according to several criteria simultaneously. To implement this system for making a decision on a protective shutdown, the following characteristic is used as input data: $TI_j\left(x_0,...,x_{N-1}\right)$, $j=1...M$ − temporary implementation of the vibration signal; M − the number of control points for the observed turbine unit. For each bearing support, vibration control is carried out at three points-directions: vertical, transverse-horizontal, axial.

Function $\phi_{1,j,\Delta}\left[TI_j\left(x_0,...,x_{N-1}\right),\tau_\Delta\right]$, $j=1...M$; $\Delta=1,2,...$ designed to calculate the RMS of the reverse component of vibration $A_{CCV,j}$ (circulating component of vibration); τ − discrete time that determines the frequency of receiving the initial vibration signals.

Function $\phi_{2,j,\Delta}\left[TI_j\left(x_0,...,x_{N-1}\right),\tau_\Delta\right]$, $j=1...M$; $\Delta=1,2,...$ designed to calculate the phase of the reverse component of vibration $\Phi_{CCV,j}$.

Function $\phi_{3,j,\Delta}\left[TI_j\left(x_0,...,x_{N-1}\right),\tau_\Delta\right]$, $j=1...M$; $\Delta=1,2,...$ is designed to calculate RMS LFV.

Function $\phi_{4,j,\Delta}\left[TI_j\left(x_0,...,x_{N-1}\right),\tau_\Delta\right]$, $j=1...M$; $\Delta=1,2,...$ is designed to calculate RMS HFV.

Function $f_{1,j,\Delta}\left(A_{CCV,j},\Phi_{CCV,j},\tau_{\Delta-1},\tau_\Delta\right)$, $j=1...M$; $\Delta=1,2,...$ is designed to calculate the increment vector of the reverse component.

Generalizing functions of the first level have the form:

$$\begin{aligned}
y_{1,\Delta} &= \Psi_{1,1,\Delta}\left[\phi_{3,j,\Delta}(\ );\tau_\Delta; j=1...M;\Delta=1,2,...\right];\\
y_{2,\Delta} &= \Psi_{1,2,\Delta}\left[\phi_{2,j,\Delta}(\ );\tau_\Delta; j=1...M;\Delta=1,2,...\right];\\
y_{3,\Delta} &= \Psi_{1,3,\Delta}\left[f_{1,j,\Delta}(\ );\tau_\Delta; j=1...M;\Delta=1,2,...\right];\\
y_{4,\Delta} &= \Psi_{1,4,\Delta}\left[\phi_{4,j,\Delta}(\ );\tau_\Delta; j=1...M;\Delta=1,2,...\right].
\end{aligned}$$

The result of each of the generalizing functions of the first level $\Psi_{1,k,\Delta}(\ )$, $k=1...4$ is $y_{k,\Delta}$, which takes two values: zero or one. $y_{k,\Delta}$ are input parameters $E_{k,\Delta}$ for the generalizing function of the second level: $z_\Delta=\Psi_{2,\Delta}\left(x_{1,\Delta}=y_{1,\Delta}, x_{2,\Delta}=y_{2,\Delta}, x_{3,\Delta}=y_{3,\Delta}, x_{4,\Delta}=y_{4,\Delta}\right)$. The result of the generalizing function of the second level z_Δ. The value $z_\Delta=1$ corresponds to the decision to trigger a protective shutdown. The value $z_\Delta=0$ corresponds to the normal mode of operation of the controlled object.

Model of a living organism that makes decisions

Currently, there is a need to monitor the state of not only technical objects, but also living organisms, including humans. Let us assume the hypothesis that a person is a material organic entity, consisting of:

− a set of various primary information converters (vision, hearing, smell, taste, receptors for assessing the state of the environment and one's own organs, nerve endings, etc.) that convert the state of the environment and the body itself into electrical signals transmitted to the neural network the human brain;

− organs of life support, survival, nutrition, reactions, working capacity, reproduction of their own kind (heart, stomach, liver, spleen, etc.);

− actuators (arms, legs, fingers, vocal cords, teeth, facial organs, etc.);

− control device − the brain, which makes decisions based on existing knowledge and received electrical signals from primary transducers, and generates control signals transmitted to actuators.

Like any other, organic human matter is subject to wear and aging, which, in the end, leads to the cessation of its activity − the death of a person. As a result of scientific research, it was found that the main functional element of the brain is what is called a neuron [5]. However, the question of the interaction of brain neurons remains problematic. On the basis of empirical and theoretical experience, it can be assumed that the general structure of the brain can be represented as a nucleus and its surrounding shell. The state of the nucleus is given to a person from birth. It defines the abilities and capabilities of a person and, most likely, does not change or is subject to minimal changes. It is possible to assume that the core of the brain can also undergo quite serious changes under the influence of strong external disturbances, for example, radiation, poisoning of the body with chemicals, the introduction of substances into the human body that affect the functioning of the biological elements of the body. The activity of the nucleus of the brain determines our abilities and exercises supreme control.

The second part of the brain is a self-learning neural network that has the ability to reconfigure, receive, accumulate information and adjust the processing functions and transmission coefficients for signals coming through the synapses to the neuron, thereby forming a decision-making system for a given moment in time, the essence of which depends on the surrounding space and the state of the organism, information about which is transmitted to the neural network by primary information converters. All actions and sensations that a person receives and reproduces are the essence and reflection of the decisions made by the neural network of the brain. Self-training of the neural network is carried out empirically, or under targeted influence, including at the request of the neural network, i. e. decisions taken by it to carry out certain actions to obtain new information.

If we follow this model, then we can argue the conclusion that human behavior is determined by the initial tuning of the neural network of the brain, and the subsequent reconfiguration of the self-learning, multilevel, volumetric neural network of his brain, which occurs as new information is received or the existing information is processed. The work of the brain is accompanied by a change in the electromagnetic field, which can be fixed by special primary transducers and converted into changing parameters of current or voltage, which happens when an electroencephalogram is taken. The electrical parameters of the brain work for each performed action are different and they tend to be repeated with an acceptable spread for each action. The issues of brain control of prostheses have already been worked out quite well, there are even developments when a person mentally controls the movement of a robotic object [9].

Studies of the work of the brain of dogs have shown that several (5–6) tasks are solved in parallel in their brain [10, 11]. The brain itself is not very fast, but it instantly switches priority to solving the most important task for it at the moment. A simple example. A person may be fascinated by watching a movie, but if his hand is imperceptibly touched by a hot object, he will instantly withdraw his hand, because the nerve responsible for measuring the temperature of the hand will detect its unacceptable overheating, transmit this information to the brain, and the brain will decide that you need to change the position of the hand and give an indication of the execution of this action.

As a result of the experiments, obtained experimental and empirical data, we assume that the material carrier of information about different events is not the excitation of different neurons, but various complexes of self-excited neurons (neural networks). New responses are produced and stored by the neural system either on the basis of the creation of new synaptic connections between existing neurons, or on the basis of a change in the efficiency (transfer coefficients and transforming functions) of existing synaptic connections. Memorization (long-term) of information is a change in the ability of some neurons to be excited when other neurons are excited.

Most likely, information in the brain is stored in the form of certain configurations of the neural network or an influencing sequence that controls the change (reconfiguration) of the neural network, including changes in the transmission coefficients at synapses. It is possible that some data associated with memorization is transmitted to the core of the brain or the core of the brain controls the processes of memorization, further storage and change of memorized information, including the level of reproduction of this information and its transmission to the shell of the brain. In the works of specialists in the field of educational methods, memory processes and psychiatry, it is said that the age peak of information assimilation occurs at the age of 25–26 years [12, 13]. When considering memory issues, this factor should be taken into account, as well as the degree of concentration of a person, since random distractions and absent-mindedness will significantly affect this process.

Of particular interest is the question of the reconfiguration of genes as carriers of information about the further exceptional features of a particular person. What affects this, why are the probabilities of the appearance of human males and females almost the same for the human population, and with a slight predominance of males? Here, perhaps, we can talk about some kind of external control and regulatory impact on the viability of the human population. At the same time, one should not exclude the possibility that in ancient times the earth was also inhabited by intelligent beings who had the ability to self-learn the brain, but the structure of their body did not allow complex effects on the environment. It is quite possible that intelligence was transferred from one living species to another with the disappearance, for some reason, of the ancestor and, in the end, the mind passed to a human-shaped species that developed into a modern person.

Mankind is increasing the amount of general information, but human primary information converters and actuators remain practically unchanged, and the complexity of decisions made by the human brain has not changed over the past millennia. If we assume that we live in a matrix, then it turns out that earthly life is a system for observing and studying the behavior of a certain reasonable set of individuals, their population. If you read or set the settings of the human brain at the beginning of life, then register external functional effects on the body, and then fix the state of the neural network and memory before the end of a person's life, then you can get a huge amount of information to evaluate the laws of development of intelligent life, taking into account various factors of influence, both physical and social, social, political, informational. Perhaps this experiment is conducted by a civilization that is at a much higher level of development. After all, humanity knows so little about the structure of the universe. Moreover, our solar system is unique in the Milky Way galaxy. None of the star systems discovered in this galaxy is similar to ours. In all discovered star systems, large planets are in near stellar orbits, and in our system, small planets Mercury, Venus, Earth, Mars are near the star, and large Jupiter, Saturn, Uranus, Neptune are in distant orbits, protecting small planets from space debris. At the same time, the distances of the orbits of the planets of the solar system have a rational mathematical relationship between them, which is also surprising. It looks like fantasy, but there is no reliable evidence that this is not reality.

It is quite obvious that all human sensations formed by the neural network of the brain are possible only in the presence of a material and living body. The absence or inoperability of the body leads to the loss of sources of primary information for the control organ of the brain, which can, in a sense, be considered the source of spirituality. If we allow the possibility of reading the state of the brain and the information stored in it, and then transferring it to another, similar or similar, subject (object), then this process can be represented (defined) as the transfer of the life of one person to another body, not necessarily human, and maybe into the body of some other creature with similar or similar capabilities, or even into an inorganic structure. At the same time, with a high degree of probability, it will be necessary to reconfigure and retrain the transferred settings and memory of the neural network to the level necessary for self-learning and decision-making by a new intelligent being.

In the limit, one can admit both organic and inorganic, or mixed, structure of this new rational entity. As a result, it seems possible to achieve eternal life enriched with new knowledge. It is likely that this is already happening, since from the birth of the human body, to its aging and death, the brain is self-learning with previously acquired and stored knowledge, as well as the creation, accumulation and preservation of new knowledge, which are transferred to a new generation of eternal life. The possibility of transferring the neural network of the human brain into an inorganic structure provides much greater opportunities for transferring life to other planets and other stellar systems, ensuring its non-disappearance.

Thus, the development of systems and means for obtaining information about the state of a person, the neural network of his brain, about their change over time and under external influence, is very relevant and will allow solving many complex problems. And the construction of decision-making systems that model individual functional elements of the brain of living beings will make it possible to give artificial intelligence systems new opportunities.

Conclusion

The proposed model of the basic element of the decision-making system allows you to configure various structures designed to assess the state of complex technical and natural objects. An example of the implementation of a decision-making system for assessing the state of a multi-support power unit is presented, as a combination of basic decision modules, which has been put into commercial operation [14–16]. The considered approach can be used in modeling various decision-making systems, including living organisms, the control device of which is a multi-level, multi-layer, volumetric neural network, the typical element of which has the form of the proposed basic decision-making element.

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