Ensuring the Properties of Functional Stability of Manufacturing Processes Based on the Application of Neural Networks

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Abstract

A large number of different publications in the field of functional stability of complex technical systems and in the field of artificial intelligence, namely neural networks, determines the need for analysis of results and their understanding in terms of assessing the feasibility of combining these areas. The characteristics of the behavior of complex technical systems that implement the property of functional stability of these systems are studied in the work. The article presents the definition of functionally stable production process of industrial enterprises and the criterion for ensuring its functional stability. Ensuring the functional stability of production processes is an important issue today. At present, many different methods have been proposed to ensure a high level of functional stability, but they need to be constantly changed and improved. Neural networks are a tool that allows you to create a deep hierarchy of decisions based on the location, type and level of the defect that occurred in the control system and, as a consequence, can be effectively used to solve this problem. Therefore, the article considers the features of the main provisions of the theory of artificial intelligence, namely neural networks, to ensure the functional stability of production processes of industrial enterprises. Based on the analysis, the article explores the possibilities of using neural networks to diagnose the state of systems and the practical application of neural network tools to detect and localize defects in systems, which is the key to ensuring the functional stability of production processes. The method of ensuring the properties of functional stability of the enterprise information system has been improved. Promising ways of further research in this area may be a wide range of issues related to the development of new and improvement of existing methods of ensuring the functional stability of production processes of enterprises, including means of artificial intelligence.

Keywords [1]

Neural network, manufacturing process, functional stability, multilayer feed forward network, radial basis network, Hopfield network, self-organizing neural network, activation function.

1. Introduction

Modern science often studies complex systems. This kind of systems form multilevel structures. Their functioning isn't described by the usual sum of interactions of the constituent elements. Complex technical systems are built to perform certain special tasks. By analogy with natural systems the development of artificial systems leads to the complication of their functioning and the emergence of new properties such as functional stability.

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The concept of functional stability and its definition were given in the works on solving specific applied problems by professor Mashkov O.A. in 1990. Then this concept was explained in solving partial problems, and a more accurate definition of the properties of the functional stability of a complex controlled system was given in [13,14]. The functional stability of the system means the property to maintain its implementation of the basic functions within the limits set by regulatory requirements, in conditions of opposition, as well as the impact of flows of failures, malfunctions and breakdowns within the time-period. There are also other approaches to the definition of this concept, which can be found in the works of Mashkov, for example, these [15-17].

In works [18-19], this topic is considered in terms of demonstrating the connection and a significant difference between the concept of “functional stability” and the concepts of “reliability”, “survivability” and “fault tolerance” at the same time. It is shown that the methods of ensuring functional stability are aimed at ensuring the performance of the most important functions, when violations and failures have already occurred (and traditional methods of improving the reliability, survivability and fault tolerance of technical systems paid more attention to reducing these violations). In [19-22] the author came to the conclusion that these approaches to increase the reliability of systems successfully complement each other without contradicting.

Initially the methods of ensuring functional stability were used to improve the technical characteristics of complex technical systems operating in extreme conditions, firs of all for aerospace systems. However, the development of the element base of computing systems, the complexity of modern and, especially, promising autonomous dynamic systems, the presence of significant constructive redundancy in them allows to expand the scope of methods for ensuring functional stability. In modern conditions, the distributed information and control systems are negatively affected by both internal (failures, errors of corporate subscribers) and external (active or passive influence of the external environment) factors. Therefore, ensuring the functional stability of distributed information and control systems is an urgent task [23-28].

The problem of ensuring functional stability can be considered as one of the current scientific problems of modern theory of automatic control.

The field of neuroscience is developing very dynamically due to new technological and theoretical means of research. This is reflected in hundreds of thousands of publications each year. In recent years, a number of methods and algorithms for solving various information and technology problems, among which one of the most effective is artificial neural networks (ANN).

Despite the urgent need to solve the described problems, it should be noted their rather weak study, the lack of clear methods for constructing and optimizing both static and dynamic complex ANN. Therefore, the work devoted to solving the scientific and applied problem of ensuring the functional stability of the automated production process based on the use of neural networks is relevant.

The aim of the work is to study such a property as the functional stability of automated production processes based on the use of neural networks. To do this, the task was to investigate the applicability of neural networks for diagnosing the state of systems and the practical application of neural network tools for detecting and localizing defects in systems, which is the key to ensuring the functional stability of production processes.

2. Features of ensuring the functional stability of complex technical systems.

Of particular interest for the study are the properties of systems that provide the ability to function when changing the parameters of the internal and external environment over long periods of time. First of all, it applies to highly organized technical and most biological systems. The property of functional stability is the ability of the system to adapt to new and not always taken into account situations and to resist any internal or external influences, while realizing its target function. It is ensured by a corresponding change in the structure and behavior of the system, even when the quality of the system is reduced. Depending on the complexity of the organization of information systems of the enterprise and the level of analysis, the property of functional stability can be manifested (and accordingly quantitatively) in the form of resistance to errors, reliability, survivability, fault tolerance, adaptability, noise immunity and more.

A fundamentally important point is the unity of activity and stability of the system. This unity is realized in the adaptive nature of its behavior. System adaptability is an environment-correlated activity. So the concepts of reliability and stability express and characterize the qualitative certainty of complex dynamic systems. The stability (reliability) of a complex system over time is a necessary condition for its holistic functioning. But this quality isn't unique to complex systems. Simple systems and bodies also have the stability (strength). It's necessary for their holistic existence.

Consider a number of concepts that characterize the reliability of distributed information systems. Failure is an event in which some element of the information system (module of the information system of the enterprise) loses the ability to perform the functions of processing, storage and transmission of information. Recovery is the event when a failed item completely restores the ability to perform these functions to process and transmit information.

The probability of faultless work $r(t)$ is characterized by the performance of the information system $\omega(\tau)$ module for a certain period of time $(0, t)$:

$$r(t) = P\{\forall\tau \in [0, t) \to \omega(\tau) = 1\}, \tag{1}$$

where

$$\omega(\tau) = \begin{cases} 1, & \text{if in } \tau \geq 0 \text{ the element is in working condition;} \\ 0, & \text{if in } \tau \geq 0 \text{ the element is in unworking condition.} \end{cases}$$

The probability of recovering a failed module is called a function

$$r(t) = P\{\forall\tau \in [0, t) \to \omega(\tau) = 1\}, \tag{2}$$

where $P\{\forall\tau \in [0, t) \to \omega(\tau) = 0\}$ – the probability that (when performing restoration work) productivity $\omega(\tau)$ remains equal to zero and characterizes the ability of an element of the information system of the enterprise to achieve a given productivity after failure.

The function of readiness is used to characterize the productivity $\omega(\tau)$ at $t \geq 0$ time (inclusive $t(\infty)$):

$$s(i, t) = p_1(i, t) = P\{i\colon\ \omega(t) = 1\ \}, \tag{3}$$

where $P\{i\colon\ \omega(t) = 1\ \}$ – the probability that, under the conditions of the flow of failures and recoveries, the module that began to function in the state $i \in E_0{}'$, will have at $t > 0$ performance equal to the potentially possible; $E_0' = \{0, 1\}$ – the set of states of the information system module; $i = 0$ – failure; $i = 1$ – in working condition; $P_j(i, t)$ – the probability of finding the element at time $t \geq 0$ in the state $j \in E_0$, provided that the initial state was $i \in E_0$.

The main ways to increase reliability are the use of different types of redundancy functional, algorithmic, technical (hardware and software), topological, temporary its organization in the form of duplicates or majority structures. One of the directions of the theory of reliability in the field of improving the quality of functioning of technical systems is to ensure fault tolerance, ie purposeful redundancy of individual parts of the system. Based on the Markov model, the main indicator of fault tolerance Q can be determined:

$$Q = \frac{\sum_{i=1}^{m} L_{Si}(z)|_{z=0}}{T_{CF}}, \tag{4}$$

where $L_{Si}(z)$ — Laplace z–transform, the probability of the system being in all failure states, except for the complete failure state S_{CF}; T_{CF} – the average operating time of the system to complete failure

$$T_{CF} = \sum_{i=0}^{m} L_{Si}(z)|_{z=0}, \tag{5}$$

where m — the number of system failure states.

The indicator Q characterizes the ratio of working time of the system in failure states to the total operating time of the system to complete failure. The higher the Q, the more efficiently the system fends off failures.

Thus, the properties of reliability and fault tolerance are necessary, but insufficient to ensure the quality of functioning of the enterprise's information system. The methodology of creating functional stability information systems allows a slightly different approach to such problems and offer methods for solving them. Survivability is the property of a system to maintain limited efficiency under external influences that lead to the failure of its components. The survivability property characterizes the ability of the system to withstand the development of critical failures in any operating conditions, including those not provided for in the documentation. Examples of functional survivability assessments are ship survivability, power system, information network, computing system, etc.

The main parameter for estimating the survivability of computing systems is a function

$$N(i,t) = \frac{\bar{\Omega}(i,t)}{N_{\omega}}, \qquad (6)$$

where $\bar{\Omega}(i,t)$ – mathematical expectation of the performance of the computing system at a certain point in time $t \geq 0$; N_{ω} – total performance of the whole system.

Therefore, the considered properties characterize the behavior of a complex system in the conditions of environmental factors that can disrupt a given mode of operation of the system: system reliability characterizes its ability to function normally in given modes and conditions; stability – the continuation of the same functioning under the influence of perturbations; survivability – the ability of the system to counteract external actions; adaptability – the preservation of some part of the system when changing set of parameters, which allows the optimal, in a sense, way to achieve the goal that was predetermined.

However, none of these properties alone reflects the concept of functional stability of the system, and all in the complex they also can not characterize it. Because they do not simultaneously reflect the active nature of the properties of functional stability under the action of unknown perturbations. The term "*functional stability*" requires a precise semantic-mathematical definition, without which this property, in many authors, is constantly reduced to one of these properties.

Functional stability of the object means its ability to maintain the ability for some time to perform its basic functions within the limits set by regulatory requirements, under the influence of the flow of failures, malfunctions, failures.

Functional stability is characterized by the capabilities of the system: to perform the established minimum amount of its functions in external and internal actions, which are not determined by the conditions of normal operation; make a choice of the optimal mode of functioning at the expense of own internal resources; restructure the structure, change the functions of individual subsystems and their behavior.

The property of functional stability is characteristic not only for biological species, but also for complex technical systems. The nature of the behavior of the system is chosen in accordance with changes in external conditions and with the functional invariant of the system, which can be called the internal purpose of its operation. The choice of behavior also implies the presence of a number of possible different consequences, combined of the general property "compliance" with one external cause in these conditions.

From the point of view of qualitative performance of functions by the system, the functional stability of the system characterizes its ability to perform the specified functions with some allowable reduction in quality. Moreover, actions on the system can be both natural and intentional. The main feature of functionally stable systems is their ability to degrade at the structural level until complete failure of the system, ie to exclude from the structure elements which failures, rebuild the structure, adjust system parameters to adapt to new operating conditions.

Thus, the available variety of the property "functional stability", which differ not only in the transition from wildlife to technical systems, but also depending on the type, purpose, method of organization of the technical system, poses two main tasks: introduction a general definition, evaluation criteria and methods to increase functional stability for information systems of the enterprise; careful study of individual classes of technical systems and determination of the most effective means of increasing their functional stability.

3. Features of ensuring the functional stability of production processes of industrial enterprises

Consider the problem of constructing a management function that ensures the execution of the production process in such a way that the result of the process guarantees the final receipt of the finished product, which meets all the parameters required by current standards. Having analyzed the problems of automation of enterprise management systems, we present a method of automation of the production process using pseudo-inversion.

The production process of a modern enterprise means a set of measures by which the production of some finished products, semi-finished products, blanks or other products. The main task of industrial enterprises is the development of new products, machinery and equipment, means of mechanization and automation, the latest technologies and more.

Each industry has its own specifics, which depends on the type of production, purpose, size and accuracy of machines, level of production and technical equipment. In the general case, automation of production is a stage of machine production, characterized by the release of the human factor from the direct performance of management functions of production processes and the delegation of these functions to information and computing systems - automatic devices and systems. Control is a targeted action on an object that ensures the optimal or specified mode of its operation within acceptable tolerances. To automate processes, there are certain requirements for the enterprise, without which it becomes inefficient and difficult to implement. First, the transition of the enterprise to the process model of management is a mandatory requirement. The transition to a process model of management is a task, the complexity of which depends on the scale and specifics of the enterprise. Secondly, an important requirement is the compliance of the current model of enterprise processes with the technical criteria used in their automation.

Note that without automation of the process of controlling the parameters of production processes at modern enterprises, it is impossible to organize mass production of quality products. To solve such problems in production plants, ensuring the stability of production processes by controlling the basic parameters of production in real time, a mathematical model is proposed, which can be integrated into an automated enterprise management system. It should be noted that any automation requires in-depth study of all processes in the enterprise as a whole and each a separate process in each production center in particular (Fig.1).

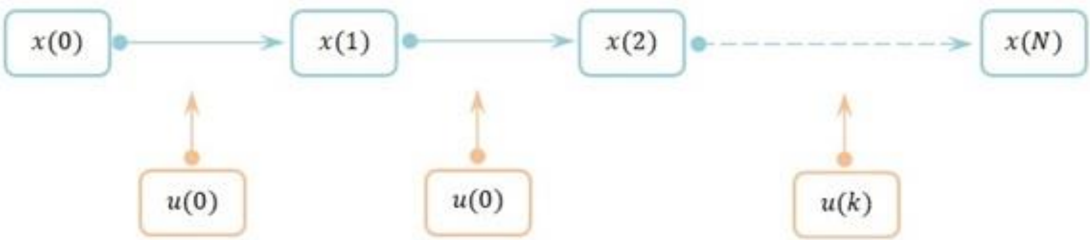

Figure 1: Topology of linear technological production process

Production usually consists of a number of stages, at each of which there are certain requirements for the parameters and characteristics of raw materials, semi-finished and finished products. Denote the following sets of parameters at each i-th stage $x(i)$, $i = 1,2, \dots N$. Technological production processes to ensure the achievement of parameters $x(i)$ at each stage require external influences on the production process – $u(i)$ (active effect, energy effect, chemical or other technological impact at each stage). It is clear that the final quality of the product, as well as the intermediate quantity at each stage depends on tight adherence to technology and ensuring control over the necessary parameters at each previous step. Next, we assume that this a priori requirement is met.

Denote:

$A(i)$ – matrix of dependence of indicators of quality of production on $(i+1)$-st stage on indicators on i stage, actually matrix of production process;

$C(i)$ – a matrix that determines the structure of influence on the production process $u(i)$.

Then the mathematical model of the technological process, provided by the information systems of the production enterprise, can be written as follows

$$x(i+1) = A(i)x(i) + C(i)u(i), \quad i = 1,2,\dots,N$$
$$x(i) \in \mathbb{R}^n, \quad A(i) \in \mathbb{R}^{n\times n}, \quad C(i) \in \mathbb{R}^{n\times m}, \quad u(i) \in \mathbb{R}^m. \tag{7}$$

Where $x = (x_1, x_2, \dots, x_n)^T$ – state vector of dimension n, u $= (u_1, \dots, u_m)^T$ – the control vector has dimension m, $A(t)$ – $n \times n$ – matrix, $C(t)$ – $n \times m$ –matrix, $t = 0,1,\dots, N-1$. Denote by $I_N = \{0,\ 1, \dots, N\};$ $x(t, x_0, u)$ system solution, $t \in I_N$ when managing $u(t)$, $t \in I_{N-1}$.

When automating such processes in practice, it is necessary to set certain management tasks that actually describe the design conditions of the control function u, which provides a controlled purposeful execution of the process. The main problem is the problem that considers the search for the control function u, which ensures the execution of the process, so that the result of the process provides the final production in $x(N)$ products that meet all the quality characteristics required by current standards. If at the end of the process the product has deviations from the specified standard parameters, then such deviations are guaranteed to fall into the set of permissible tolerances, which are defined by the current standards for such products. Mathematically, this means that there is a desired final state x_N and a positive parameter $\varepsilon > 0$ such that

$$\|x(N) - x_N\| < \varepsilon. \tag{8}$$

Let $\bar{x} = \begin{pmatrix} \bar{x}(0) \\ \bar{x}(1) \\ \vdots \\ \bar{x}(N) \end{pmatrix}$ — reference process. The reference process guarantees full compliance with the set of parameters $x(k)$, $k = 0,1,\dots,N$, which should be followed in the ideal execution of the production process at all stages and at each of the links. This is a certain median value, which simultaneously assumes the presence of an a priori set of permissible deviations of the system parameters. The parameter $\varepsilon > 0$ is set, which determines the set of permissible deviations (tolerances) from the reference values.

Definition. *If for the data of matrices A, C and vector u there exists a solution $x = \bar{x} + e$ of system* (7) *such that $\|e\| \le \varepsilon$, then such a technological process will be called functionally stable*.

A valid theorem.

Theorem. *Let the condition be fulfilled*

$$u^T Q u = 0, \tag{9}$$

where $Q = C^T Z(A^T) C$, $Z(A^T) = E - AA^+$ – projector on a matrix core A^T, A^+ – pseudo-inverted matrix. With

$$\|A^+(Cu - A\bar{x})\| \le \varepsilon. \tag{10}$$

Then the technological process described by equation (7) *is functionally stable.*

Thus, ensuring the functional stability of the technological process depends on the ability to ensure process management in each production center and control the defects that occur and their location.

Thus, the task of detecting and localizing defects becomes increasingly important with increasing complexity of control systems and requirements for them. Detection of defects and malfunctions in the operation of facilities is also important in terms of reliability, fault tolerance, survivability and actual functional stability of complex technical systems.

4. Substantiation of the possibility of using neural networks to ensure the functional stability of production processes

Neural networks are a tool that allows you to create a deep hierarchy of solutions based on the location, type and level of the defect that occurred in the control system, and therefore can be used in diagnostics.

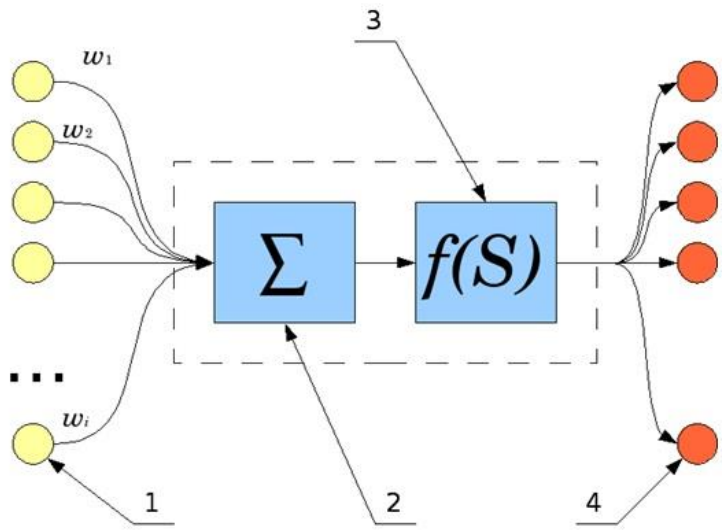

Figure 2: Neuron model. (1) Neurons, the output signals of which are fed to the input of this neuron. (2) The adder of input signals. (3) The calculator of the transfer function. (4) Neurons, the inputs of which are fed to the signal of this neuron. w_i- the weight of the input signals.

A neuron (nerve cell) is the main element of the nervous system that processes information. McCullock and Pitts proposed using a binary threshold element as a model of an artificial neuron. Mathematically, an artificial neuron is usually represented as a non-linear function from a single argument - a linear combination of all input signals. This function is called the activation function or the start function, the transfer function. The result obtained refers to one result. Such artificial neurons are connected in a network - they connect the outputs of some neurons with the inputs of others (Fig. 2). This mathematical neuron calculates the weighted sum of several output signals, compares the received signal with the threshold value and supplies the received signal to the input of the unit that implements the function of activating the neuron.

Mathematically, a neuron is a weight adder, the only output of which is determined through its inputs and the weight matrix in this way

$$y = f(u), \;\; u = \sum_{i=1}^{n} w_i x_i + w_0 x_0, \tag{11}$$

where w_i and x_i — respectively, the signals at the inputs of the neuron and the weight of the inputs, the function u is called the induced local field, and $f(u)$ is the transfer function. Possible values of signals at the inputs of the neuron are considered to be given in the range $[0,1]$. They can be discrete (0 or 1) or analog. The additional input x_0 and the corresponding weight are used to initialize the neuron. Initialization means a shift in the activation function of the neuron along the horizontal axis, ie the formation of the threshold of sensitivity of the neuron. In addition, sometimes a random variable called a shift is added to the output of the neuron. The shift can be seen as a signal of an additional, always loaded, synapse.

The transmission function $f\ (u)$ determines the dependence of the signal at the output of the neuron on the weighted sum of signals at its inputs. In most cases, it grows monotonically and has a range of values $[-1,1]$ or $[0,1]$, but there are exceptions. The artificial neuron is completely characterized by its transmitting function. Note that some network learning algorithms require that the network be constantly differentiated along the entire numerical axis.

A neural network is defined as an interconnected set of neurons. The diversity of neural network models is determined by the existence of different activation functions and the topology of their communication and interaction. The network acquires knowledge in the learning process. Learning neural networks is understood as a purposeful process of changing weight values in an iterative way until the network acquires the necessary properties. The learning process is based on a set of learning data, which, in fact, is a set of input signal vectors and their corresponding output signal vectors. In the process of learning, the input from the training set is sequentially fed to the input of the neural network. Then the degree of deviation between the desired and actual network outputs is calculated.

Then, using a certain algorithm, the weights of the neural network change in the direction of reducing the error. It turns out [3], with a small number of interneuronal connections, Newtonian methods are the most effective, and with 10^3 3 connections, the method of conjugate gradients usually shows the best results.

These groups of methods are local. To achieve the global minimum, evolutionary algorithms for learning neural networks have been developed, a clear representative of which are genetic algorithms. Therefore, the learning procedure can begin with a genetic algorithm, and when a certain threshold is reached, the genetic algorithm is replaced by a local algorithm.

Through training, the network acquires the ability to respond correctly not only to training data, but also to process other data from an acceptable set. In this sense, it is said that the neural network has the ability to generalize. The learning error is due to a lack of approximations made by the finite size network and incomplete information provided during the learning process.

The most common tools for solving image recognition, classification, and prediction problems are the following types of neural networks: multilayer feed forward network, radial basis network, Hopfield network and self-organizing neural network.

The multilayer feed forward network or reverse error can use a neuron with any differentiated transmitting function. The network consists of layers, and each neuron of the previous layer, as a rule, is connected to all neurons of the next layer. By recognizing images, this network constructs dividing surfaces in the form of nonlinear surfaces in multidimensional space. Preferably used neurons with sigma transfer function of the form

$$\sigma(x) = \frac{1}{1 + \exp(-\alpha x)}, \tag{12}$$

where α parameter of the function that determines its steepness. When $\alpha \to \infty$ the function degenerates into a threshold. When $\alpha = 0$ the sigmoid degenerates into a constant function with value $0{,}5$. The range of values of this function is interval $(0{,}1)$. A derivative of this function

$$\frac{d\sigma(x)}{dx} = \alpha f(x)\big(1 - f(x)\big), \tag{13}$$

can be expressed in terms of its value, which facilitates the use of this function when studying network backpropagation algorithms. Neurons with this transmission characteristic amplify strong signals much less than weak ones because areas of strong signals correspond to the delicate parts of the characteristic.

The radial basis network uses a neuron with the so-called potential transfer function, in the role of which the Gaussian function is most often used $f(x) = \exp(-(x - c)^2)$. Such networks are especially effective when a large number of learning vectors are available.

The Hopfield network belongs to the class of recurrent neural networks. The outputs of the last layer of the network are the inputs of the first level. Such a structure for a finite number of time cycles provides convergence with one of the specified classes, ie it is a network without a teacher (learning without supervision). It is sometimes called associative memory.

The self-organizing neural network use a special competitive mechanism. It is also a network without a teacher. The learning technology is called “

The winner takes everyone”. Only a neuron or a group of neighboring neurons that have won a competition are able to adjust their weight. Such networks perform data clustering because, after training, when the input vector is fed to the network input, the neuron responsible for the group of most similar learning vectors will be activated.

Thus, we substantiated the possibility of using neural networks to ensure the functional stability of the production process.

It is shown that neural networks are a tool that allows you to create a deep hierarchy of solutions, taking into account the location, type and level of the defect that occurred in the control system. At the same time, ensuring the functional stability of production processes, the greatest attention should be paid to improving the diagnosis of the current parameters of production processes.

5. Features of application of neural networks in the process of diagnostics of production processes and complex technical systems

In [4-6] it was shown that a conventional multilayer neural network of direct signal propagation with an arbitrary activation function can approximate any function with a given accuracy, provided that there are a sufficient number of neurons in the hidden layer. In [7] the possibilities of approximation of functions to radial basis networks are given. In accordance with the fact that the task of diagnosis involves the reflection of the space of signs in the space of states or classes of defects, in technical diagnostics are most common multilayer neural networks of direct propagation, radial core networks and neural networks with self-organization.

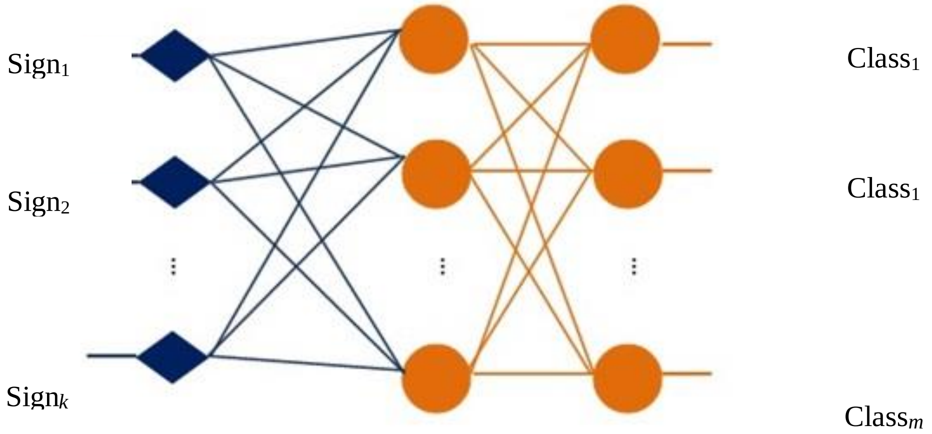

Figure 3: Neural networks for classification

To apply diagnostic methods to the class of nonlinear systems in the general case, it is necessary to linearize the model. However, the linearized model does not fully reflect the properties of systems with pronounced nonlinearities. One of the advantages of a neural network is the ability to approximate any nonlinear function using the appropriate network architecture. Therefore, the model of a dynamic system and a network observer can be built on the basis of a neural network. The mismatch between the outputs of the object and the inputs of the network in this case will be room for diagnostic signs. In particular, in [8] radial basis networks with a spline of the thin plate type (spline-surface) are used to create a model of a nonlinear chemical process, the potential function of which has the form $f(x) = (x - c)^2 \ln(x - c)$. The surface of the spline allows you to smoothly restore the function of several variables on an arbitrary end grid of points.

The most common in the problem of detection and localization of defects neural networks were as an algorithm for decision making (Fig. 3).

This solves the typical problem of pattern recognition. The main task is to assign the vector of diagnostic features to the appropriate class, ie to find the relationship between the diagnostic space and the possible states of the defect. In this case, neural networks of direct signal propagation and neural networks with self-organization are most often used for diagnosis.

In [2], a neural network with one hidden layer is used to build a test diagnostic system with a pneumatic valve. The network inputs are various parameters of the transient function of the system (overregulation, response delay, static error, time to reach the maximum value, etc.). Note that the network has three outputs. It is unusual that the outputs do not indicate the presence of a certain class of defect, as in the vast majority of studies (only one of the outputs is an indicator of the class of normal operation), and the size of a certain defect (in this case a leak in the diaphragm and valve blockage). Thus the problem of detection, localization and definition of size of defect of unit of the equipment of a certain working center of the industrial enterprise is solved. In [9], multilayer neutron networks and radial networks are used to diagnose an energy object. The neural network has 15 inputs that characterize the physical parameters of the object, such as temperature and pressure. The results presented in this paper indicate that multilayer neural networks allow to achieve greater generalization in contrast to radial networks. Although radial networks do not give the same result as direct distribution networks, their advantage is the speed of learning.

In [3, 10, 11], self-organizing neural networks known as Kohonen maps are used for diagnosis. Self-organized neural network [3] is used to diagnose equipment failures. It uses the ability of the network to compress data, ie to represent many points by a vector of weights of one neuron. The principle here is the assumption that each class of defects generates a certain change in the characteristics of the equipment. The neuron that won the competition is characterized by either normal operation or a malfunction.

Neural networks with self-organization activate a single neuron, which allows you to find the damaged element regardless of the state of the rest. In [10], a self-organizing neural network with weight limitations is used to detect sensor defects (constrained Kohonen network). This allows you to correctly classify defects, even if the system input depends on the state of the system or when the zero sensors are drifting. In [11], the Kohonen neural network is used to diagnose the chemical process of metal melting.

Thus, to ensure the functional stability of technological processes of industrial enterprises [1], it is possible to widely use different classes of neural networks to diagnose the state of equipment in each production center. Training neural networks, taking into account the state of functional stability of the technological process, will ensure the effective operation of both production equipment and current quality control of products in accordance with a certain system of tolerances.

6. Conclusions

This method is used from the existing ones, which suggests and discusses the feasibility of using artificial neural networks to ensure the functional stability of production processes, and education offers the necessary and affordable conditions proposed by the author that the production process will implement the reference requirements. For the first time, such a program is evaluated, and the features of such a neural network program are considered. A wide range of issues related to the development of new and improvement of existing methods of ensuring the functional stability of production processes of enterprises, which should operate autonomously under the influence of external and internal destabilizing factors, can be promising ways of further research in this direction.

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