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S.S. Antsyferov
Moscow State Technical University Mirea, Russia
Russia, 119454, c. Moscow, Vernadsky ave., 78

Standardisation of Indicators of Quality of Products Cognitive Technologies

С.С. Анцыферов
Московский государственный технический университет МИРЭА, Россия
Россия, 119454, г. Москва, пр. Вернадского, 78

Стандартизация показателей качества продукции когнитивных технологий

С.С. Анциферов
Московський державний технічний університет МІРЕА, Росія
Росія, 119454, м. Москва, пр. Вернадського, 78

Стандартизація показників якості продукції когнітивних технологій

The standard set of quality indicators, reflecting the principal features of functioning and development of intellectual systems is proposed. Comparative assessment of some of them is given.
Key words: indicators of quality, cognitive technologies, intellectual system, neural network, probability, interpolation, stability, structure, processing speed, reliability.

Предложена стандартная совокупность показателей качества, отражающая принципиальные особенности функционирования и развития интеллектуальных систем. Дана сравнительная оценка некоторых из них.
Ключевые слова: показатели качества, когнитивные технологии, интеллектуальная система, нейронная сеть, вероятность, интерполяция, устойчивость, структура, быстродействие, надежность.

Запропонована стандартна сукупність показників якості, що відбиває принципові особливості функціонування і розвитку інтелектуальних систем. Дана порівняльна оцінка деяких з них.
Ключові слова: показники якості, когнітивні технології, інтелектуальна система, нейронна мережа, вірогідність, інтерполяція, стійкість, структура, швидкодія, надійність.

Introduction

With the development of scientific and technical progress are complicated manufactured products and technology of industrial production, expanding range, increases the frequency of turnover of products and technologies, increasing knowledge intensity of production. In industrialized countries, conducted active research in the field of high technologies such as nano-, bio-, information and cognitive technologies (NBIC). The result is the production of materials with fundamentally new properties, the development of supercomputers and quantum biocomputers, intelligent information processing systems. Important from this point of view, the document is adopted in our country in the 2011 Presidential Decree «On approval of the priority directions of science and technology in the Russian Federation and the list of critical technologies of the Russian Federation». One of the priorities recognized «Industry of nanosystems» and in critical technologies – «nano-, bio-, information, cognitive technologies».

In technical terms, cognitive technologies – technologies that build intelligent systems (IS), the type of operating the human nervous system and having its capabilities, and in some respects – superior in the organization of complex behavior in dealing with intellectual problems [1-12]. From a practical point of view, important to establish some standard range of quality indicators (parameters) adequately characterize the fundamental features of construction, operation and development of IS, as well as standard methods (methods) to evaluate these parameters [4], [7], [11]. These issues are currently in the initial stage of theoretical study, but as market saturation IS their relevance will only increase.

Indicators of quality of IS

The main indicator of properties of IS such as «plasticity», the ability to effectively solve complex problems and achieve the goal, adapting, altering their behavior as conditions change, keeping the goal is integrity – law, manifested in appearance, the appearance of a system of new properties missing from its constituent elements. This figure assumes that the properties of IS as a certain whole, depend on the properties of its constituent elements, without being a simple sum of these properties. Furthermore, it is assumed that the combined elements of the system must have, within certain limits, the variability in the properties when combined system – they lose part of or acquire new ones. Dual with respect to the integrity indicator is additive index of the state of the system as it disintegrated into independent elements. This is an extreme case where the system itself no longer exists. Real evolutionary system is, as a rule, between the state of absolute integrity and absolute additivity and generated state of the system (its "slice") can be characterized by the degree of manifestation of one of these properties, or a tendency to its escalation or reduction [8]. The evaluation of these trends can be used such indicators as progressive factorization – aspiration system to a state with an increasingly independent elements, and progressive systematization – the desire to reduce the independence of the elements, i.e. to greater integrity. In the system analysis uses comparative quantitative assessment of the degree of wholeness α and of the use factor of the elements properties β. Parameter α characterizes the relative connectivity elements of the system and the parameter β characterizes the relative freedom of the elements. In the case of absolute wholeness: $\alpha = 1$, $\beta = 0$, progressive systematization: $\alpha > \beta$, progressing factorization: $\alpha < \beta$, absolute additivity $\alpha = 0, \beta = 1$. $\alpha + \beta = 1$ – the basic law of systems.

With indicator of wholeness closely related indicators of IS such as communicativeness and hierarchical pattern. *The communicativeness* – characterizes the ability of the system to form a complex unity with the environment. It should be understood that any system under study is an element of a higher order, and the elements of each system studied, in turn, generally act as a low-order system. From this it follows that IS is not isolated from other systems, it is associated with a variety of communications media. A medium should be understood as the totality of all objects whose properties change affects the system, as well as those objects whose properties change as a result of the system's behavior.

The hierarchical pattern – characterizes the degree of subordination, structural ordering system construction. Higher hierarchical level provides guiding influence on the underlying level, subordinate, and this effect is manifested in the fact that the hierarchy of subordinate elements acquire new properties that are absent in them in isolation, but as a result of these new properties, a new, a different aspect of IS. Thus created a new IS acquires the ability to implement new features, what is the meaning of education hierarchies.

Distinguish a number of important indicators of IS.

The self-organization – characterizes the ability of the system to reach a new level of development and, in particular, are increasingly manifest properties such as the ability to resist entropy processes and develop anti-entropic (negentropy) trends, adapt to changing conditions, if necessary, transforming its structure while maintaining certain stability. The features of self-organization are:

– the unsteadiness (variability, instability) of the individual parameters of the system and its stochastic behavior;

– the unique and the unpredictable behavior of the system under specific conditions, manifested in the system due to the presence of active elements and at the same time limiting possibilities defined properties of the elements and structural constraints;

– the adaptability – the ability to adapt to changing environmental conditions, interference, as emanating from the environment and influencing the system and internal;

– the disequilibrium – the system is fundamentally unstable condition and furthermore, seeks to maintain in this state;

– the negentropic – the ability to resist entropy (deplete system) trends due to the presence of active elements that promote information exchange with the environment and the actual process of self-development;

– the variability in behavior and structure, the ability to reach a new level of equifinality, while maintaining the integrity and basic properties;

– the ability and the willingness to goal formation, when the goals are not set from the outside, but are formed within the system.

These features are inconsistent, in most cases they are both positive and negative, desirable and undesirable. They are not immediately possible to understand and explain to select and create the desired degree of their manifestation. Conflicting particularly developing systems must constantly monitor and reflect on models and look for methods and tools that enable them to measure (assess).

The adaptability – the ability of the system to show purposeful, adaptable behavior in difficult conditions (media). Adapting to the environment allows the system to achieve this goal in the case of insufficient a priori information about the environment [3, 5, 6]. If the system can not adapt to changes in the environment, then it dies. In the process of adaptation may change the quantitative characteristics of the system, its structure, the functioning and behavior. The most complex form of adaptation have intellectual – self-organizing systems. In this study of adaptive mechanisms leads to the analysis of complex problems contradictions stability and freedom of choice, which play an important role in ensuring the development of the system and adapting to changing conditions, i.e. to study the stability problem of developing systems [8].

The stability – the ability of the system to return to equilibrium after it was withdrawn from this state under the influence of external and in systems with active elements – internal disturbances. The simplest case of steady-state system is a balance – a state in which the system remains indefinitely in the absence of disturbances. IS are self-organizing systems with active elements, so their stability should be seen as a reflection of a binary nature of natural processes: stability – handling, stability – development. In the most general form the stability of the IS is the ability of system to restore the original or close to original mode for a small infraction and continue normal operation with a sharp violation of the regime, keeping its former state qualitatively described system parameters.

The processing speed – is characterized by the following parameters: – time to return the system to equilibrium after the influence of disturbances; – time to adapt to new conditions; – time recognition, decision.

The reliability – the ability of the system to maintain its function in case of failure of any number of constituent elements.

Estimation of the properties of IS

The benchmark for comparison when evaluating the properties and functionality of the IS in cognitive technologies is often the human brain.

The main way of understanding the processes occurring in the brain, understanding the available experimental data, posing new challenges is the construction and study of mathematical models that are consistent with the data on the architecture, functions and features of the brain. Thus, in accordance with nonlinear mathematical models, processes such as perception, learning, thinking and other brain functions caused by collective process leading to the coordinated work of ensembles of neurons. Self-organization of these ensembles and is the key to explaining the functions of the brain. The exceptional efficiency of the brain in dealing with a huge number of tasks is explained by the work of the set of "elementary processor" and perfect the system architecture, which effectively "parallelize" task. Attempts to create computers with a high degree of parallelism – multiprocessor systems, transputers, cellular automata have shown that the establishment of parallel algorithms, the use of which part of the computer system do not interfere with each other and not too long waiting for the results from the other parts, is a very complex task. Nevertheless, the results of studies in neuroscience are widely used for the creation of new computer architectures and giving a kind of intuitive computing, associative memory, ability to learn and generalize the information received [10].

Currently, the most common model in neuroscience is the Hopfield neural network. Dynamics of Hopfield network is determined by the known relations for discrete dynamical systems:

$$S_i(t+1) = sign\left[\sum_{j=1}^{N} J_{ij} S_j(t) - \theta_i\right], \quad 1 \le i \le \mathrm{N}, \quad t = 1, 2, \dots,$$

where $S_i(t+1)$ – the state of the *i*-th neuron in the time $t+1$;

$S_j(t)$ – the state of the *j*-th neuron in the time *t*;

J_{ij} – the link weight of the *i*-th and *j*-th neuron;

θ_i – the local threshold at above which the *i*-th neuron becomes active state;

N – the total number of neurons.

In the Hopfield model, the values θ_i of the threshold parameters are chosen to be zero, and the matrix relations defined by the rule learning Hebb, when the links are set primarily between neurons, which when executed by one task are in the same, such as the excited state. In the Hopfield model, it corresponds to an increase of link weight J_{ij}, for example, between the *i*-th and *j*-th neuron. According to the model, an important characteristic of the neural network is the ratio of the number of key images M that can be stored to the number of neurons of the network N : $\gamma = M / N$. For the Hopfield model is often quoted value γ = 0,14, however, as the experts, actually γ much smaller. For many nonlinear systems in which the possibility of collective processes can be distinguished leading variables, the so-called order parameters, which are adjusted all the other degrees of freedom of the system studied. For the Hopfield model parameters such as the correlation between the images appear.

The Hopfield model has two major drawbacks. The first is connected with the existence of «ghosts», «phantoms», «false images», i.e. «false memory». By training the neural network by Hebb rule, along with the «real», the desired image appears set parasitics. The second shortcoming is that the network is not able to say «i do not know», she recognizes, even if it had no reason to. To compensate for these deficiencies is used generically modified Hopfield model, based on the use of sophisticated neuron model whose behavior as strong influences (hyperpolarizing or depolarizing) is regular, and at some intermediate impact – chaotic. Analysis of the generalized Hopfield model showed that this neural network is able to «fight» with false images, making them unstable corresponding fixed points. At the same time, the less similar to the presented image previously stored, the longer it takes for neural network decision. Normally, when the numerical experiments, before the neural network to recognize the task of the presented randomly in a finite number of steps. After this time the network may be in one of three states:

– correct recognition, the probability of which P_1;
– mistaken recognition whose probability P_2;
– condition «do not know» when the neural network is still in the stage of «reflection», whose probability P_3.

The link of these probabilities with the number of steps before a decision is studied in [12].

The main task for the Hopfield model – creating systems with associative memory. However, there is a wide class of problems, the solution of which it is desirable that the system had some semblance of intuition and was able to learn from their mistakes. One such problem is the identification of the function at a given point in space by a set of known values at other points. Difficulties associated with the fact that the space can have a very high dimensionality that is typically, for example, for diagnosing problems of complex disease [1], [2], and this compact space region corresponding to a certain state (diagnosis) may be sufficiently complex geometry, especially not be convex. Another problem associated with the forecast value of some quantity for a number of its previously measured values. Both of these problems can be reduced to the problem of interpolation. Interpolation theory is one of the most developed areas of computational mathematics. However, the attempt to use most of the algorithms in the case of high-dimensional space, or in situations where the numerical values (measurements) are given with an accuracy, encounters great difficulties [13], [14]. Even the task of finding neighbors in a multidimensional space may be quite simple and not require the use of special numerical methods.

The neural networks can satisfactorily solve interpolation problems based on them manage to create recognizing, diagnosing and forecasting systems. . Especially the great potential of three-layer networks. A key issue for these networks is associated with the creation of effective learning algorithms. One of the most well-known, simple and reliable algorithm is backpropagation algorithm, which provides the possibility of correcting the balance in reverse passage in the case of incorrect recognition. However, this algorithm has a number of important limitations:

– define a local rather than a global minimum of the potential function;
– at training multilayer network may be a phenomenon called «network paralysis», which manifests itself in the fact that, despite the long time of training, the error may not decrease substantially, while remaining sufficiently large due to the weak, under certain conditions, the reaction network correction weights.

The neural networks can be used as a tool for modeling various nonlinear systems. They are a kind of prototype information complexity [10], typical for a number of physical, biological and technical systems, simulation model of the process.

Note the common signs of IS of most promising, symbolist-connectivity type. First, it is a large number of constituent elements and their connectivity, creating new properties (new quality) of the whole, can not be reduced to the properties of constituents, but at the same time, in some way determined by the properties of the parts. In turn, the composition and properties of the elements in some way determined by the properties of the whole. Second, the presence of stable structures and interactions between the elements that combine elements into a whole. Thus, human brain contains about 10^{12} neurons can be represented as a state space 10^{12} measurements. Typical stable structure consists of approximately 10^8 items. In the space of states with 10^8 measurements and 10 levels of neuronal excitation exists about 10^{10^8} certain provisions, representing excitation vectors. In the presence of about 10^5 synaptic connections between each neuron and the other 10^8 neurons stable structure, it is necessary to distinguish between approximately 10^{13} synapses.

Consequently, for 10 specific weights at each synapse only one stable structure there is a huge amount of weights $10^{10^{13}}$. This complexity provides limitless opportunities for encoding, representation and processing of information. Even more of the brain determined by the number of stable structures (number of connections). According to a mechanistic approach possible number of links proportional to N^2, where N – number of elements to be linked, the number of neurons. However, in accordance with the cognitive approach, the actual number of links $M \approx N \ln N$, i.e. elements "select" the most important and valuable connections, forming under the influence of the information field connected together [9], [10].

Thus, the study of American scientists to analyze the visual cortex have revealed important structural feature in the organization of the brain – the neurons with the same function are grouped in columns, a sort of connected sets representing local neural networks, piercing bark. In the theory of cognitive systems is used as an indicator of quality «cognitive factor» $CF = M / N^2 = (N \ln N) / N^2 = (\ln N) / N$, which shows that the connected set of (stable structure), folding in the information space, give the greater the effect, the greater the number of elements N they connect. It is assumed that the lower the value the *CF*, the greater the effect, the higher the level of intelligence of *IS*. Evaluating the level of intelligence as $LI = 1/CF$ to the brain $LI = 1/27 \cdot 10^{-12} \approx 3{,}7 \cdot 10^{10}$.

Assessing the performance, it should be noted that the quantitative characteristics computer vastly superior brain. The velocity of propagation of the electrical signal is about 10^8 m/s, and the clock speed of modern computers $\approx 10^9$ Hz. The speed of propagation of the nerve impulse ~ 100 m/s. Nevertheless, as noted above, the work of the brain in solving intellectual problems much more efficient computer systems.

As for the reliability of IS, there is taken to distinguish the reliability of information storage and reliability of pattern recognition. The results of studies of human memory and animals have shown that the brain is no one clearly localized structure for the storage of information. In this case, the storage system is likely and the distributed nature of the failure of its components leads to failure of the entire system. Compared with brain computer components are highly unreliable structures. Failure of any of them may indicate failure of the entire system. Great prospects improve of indicators of quality of IS, along with nanotechnology involve using methods biocybernetics.

Abstracts

– The set of indicators of quality basic products cognitive technologies – intelligent systems is proposed.

– Comparative assessment of some indicators of artificial intelligence with rates of natural intelligence is given.

– Using advances of nanotechnology industry and biocybernetics in IS of neurological type will allow, apparently, in the near future much closer to the quality indicators of natural intelligence.

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RESUME

S.S. Antsyferov

Standardisation of Indicators of Quality of Products Cognitive Technologies

In technical terms cognitive technologies is the technology of construction of intellectual systems (IS), functioning according to the type of the human nervous system and possessing its guests, and in some respects – exceeding in the organization of complex behavior in solving intellectual problems. From a practical point of view seems to be important to establish some standard nomenclature of indicators of quality (parameters), adequately characterizing the principal features of the building, functioning and development IS, as well as standard methods (techniques) assessment of these indicators. These questions are currently in the initial stage of theoretical development, but as the saturation of the market IS their importance will only grow.

The basic indicators of the quality of IS may act integrity, hierarchy, self-organization, adaptability, stability, processing speed and reliability. The standard of comparison in evaluating the performance of the quality of IS serves as the brain of the person or its mathematical model. The most common model is the Hopfield neural network.

The main task for Hopfield model is the creation of systems possessing associative memory. However, there is a wide class of problems, for solution of which it is desirable that the system had a certain similarity of intuition and was able to learn from their mistakes. One of such tasks associated with the definition of the function values at a given point in space at a known set of values at other points. Difficulties related to the fact that the space can be very high dimension, which is typical for the problems of diagnostics of complex diseases, while a compact region this space corresponding to certain states (diagnoses), can be rather complicated geometry, in particular, not be convex. Another challenge is to forecast the values of some size on a number of its previously measured values. Both of these problems are reduced to the problem of interpolation.

The neural networks are quite satisfactory to solve interpolation tasks, on their basis it is possible to create recognize, diagnostic and prediction systems. Especially the great potential of three-layer networks. The main question for these networks is associated with the creation of effective learning algorithms.

The neural networks can be used as a tool for the simulation of different nonlinear systems. They are a kind of prototype of informational complexity typical for a number of physical, biological and technical systems simulation model of the investigated process.

Use of the achievements of nanotechnology and bio-cybernetics in IS of neurological type will, apparently, in the nearest future much closer to indicators of quality of natural intellect.

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