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SYSTEM-INFORMATION APPROACH TO UNCERTAINTY OF PROCESS AND SYSTEM PARAMETERS

The **subject** matter of research in the article is a system-information approach to the uncertainty of the parameters of processes and systems of the technosphere as one of the scientific directions of using information theory in metrology and other scientific areas. The system-information approach is based on the definition of the term "information" of the properties of the system, its content and meaning. The solution of the basic problem in metrology, obtaining "information" of the quantitative characteristics of the true value of the properties of objects and phenomena that reveal the regularities of the environment, is a complex scientific problem. The instrument for obtaining information about the properties of the system is the measurement process. One of the directions in the development of measurement theory is the concept of uncertainty. The **goal** of the work is to research of non-traditional solutions to problems of technical-cybernetic systems based on the system-information approach to the uncertainty of the parameters of processes and systems. The article solves the following **tasks**: to analyze the assessment of the parameters of technological processes and systems based on the system-information approach; to develop system-information methods and algorithms for the effective use of discrete-probabilistic information in technical-cybernetic systems; to develop principles and approaches for using the system-information assessment of the uncertainty of the Planck units, use of system-information modeling in various scientific directions. The following **methods** are used: system-information approach to processes and systems, methodology of system-information modeling of the measured value; system information methodology for the assessment of the measured quantity and uncertainty. The following **results** were obtained: developed a system-information methodology for assessing the nominal parameter has been developed, which provides indirect control over the independent parameters associated with it; systemic and information methods for the effective use of discrete-probabilistic information in technical and cybernetic systems have been developed; a system-information methodology for calculating the energy equivalent of product performance indicators has been developed; the principle of calculating the efficiency of manufacturing a product based on the energy equivalent of Planck units is formulated. **Conclusions**: The solution of the set tasks on the basis of the system-information approach to the uncertainty of the parameters of processes and systems makes it possible, from the system-information point of view, to study the regularities of the stages of the life cycle of technical-cybernetic systems and conservation laws.

Keywords: system-information approach; discrete probabilistic information; uncertainty; Planck units.

Introduction

Mankind for a long time has paid attention to the definition of the term "information". But until the beginning of the 20th century, this question belonged to the philosophical category. The key question regarding the information was how to quantify it. Such scientists as R. Hartley, R. Fischer, W. Ashby, N. Wiener, K. Shannon, A.N. Kolmogorov and others dealt with this issue. As a result of research in the field of information, information theories have been developed, which are based on different scientific approaches: probabilistic (K. Shannon), synergetic (V.B. Vyatkin), quantum (A.S. Kholeva), system-information (S.V. Lutskiy) and others.

System-information (SI) approach to the processes and systems of the technosphere is one of the scientific directions in the field of information theory. Technosphere is an object of planetary ecology [1], part of the ecosphere, which contains artificial technical structures that are manufactured and used by man. Theoretical principles of SI approach to processes and systems are based on the scientific principle of "reflection" of the properties of interacting objects of any nature from the threshold of sensitivity of these objects to external influences and are identified as values of physical quantities (PQ), their location in space and time. "Reflection" is a fundamental property of the universe, which underlies the evolution of the universe. From a mathematical point of view, this is a "transformation", ie a function.

The SI approach is based on the definition of the term "information", its meaning and significance in the

system. The methodology of the SI approach is designed for information research of systems such as physical, biological, social, technical, cybernetic and use in engineering and scientific disciplines such as general systems theory, systems science, cybernetics, systems engineering, thermodynamics, systems dynamics, metrology and so on..

An important scientific and economic direction in the field of research from the standpoint of the SI approach is technical and cybernetic systems. With the development of mankind, technical and cybernetic systems are becoming increasingly complex, both in terms of mechanics and control. With the complexity of technical and cybernetic systems, the requirements for the safety of their manufacture, operation and disposal increase.

The basic difficulty of knowing the properties of systems is manifested in obtaining information on the quantitative characteristics of the true values of the properties of objects and phenomena that reveal the laws of the environment. The tool for obtaining information in the system is the measurement process. One of the directions of development of the theory of measurements is the concept of uncertainty. The concept of uncertainty is based on an "observer" who cannot obtain information about the true value of a measured quantity, but can only determine the range of values in which there is a true value of the quantity. The properties of the technical-cybernetic system, as a complex of interacting components, are in information equilibrium and have a stationary character with constant over time indicators of the distribution of probabilistic characteristics. The

scattering interval of the parameters that characterize the properties of the technical-cybernetic system is the uncertainty interval.

Control of information of the limits of the expanded uncertainty of parameters is extremely important for safety of operation of technical and cybernetic systems and environment. This information is necessary for the timely response of the management system to crisis situations - that is, to the unforeseen exit of the limits of the interval of extended uncertainty beyond the tolerance of the parameters of processes and systems and their prevention.

The parameters of technical-cybernetic systems are to some extent related by the relationship based on the information they possess, and their accuracy (uncertainty) tolerances are also related. This makes it possible, based on the information of the controlled parameter and its uncertainty, to control the algorithm of other parameters and uncertainties associated with it, as well as to predict their future state. SI approach, as a tool for analysis and synthesis of systems lays the information relations of objects at the initial stages of the product life cycle, which allows to solve problems in the development, manufacture, operation and disposal of technical cybernetic systems on the same system-information basis, and combines mechanical and cybernetic components of the system with one unit of measurement of parameters, which greatly simplifies and reduces the cost of digitization at the stages of the product life cycle.

Therefore, it is important to study non-traditional solutions to technical and cybernetic systems based on the SI approach to the uncertainty of the parameters of processes and systems that have emerged in new non-traditional fields of science and technology.

Analysis of literature data, problem statement

SI approach to processes and systems reveals the system and information characteristics of objects, which reflect the regular relationship between them [2]. The result of this relationship is the reflection of information. Information relations in the universe are absolute and comprehensive, both directly and indirectly. The category of time and space characterizes the intensity of information. Information in the system-information approach to processes and systems reveals not only quantitative characteristics, but qualitative and value [3].

Information is a fundamental quantity; it cannot be expressed through other basic quantities. Information contains the content of the system about itself and is an intrinsic property. Mathematically, information is defined as a measure of the order of a set consisting of different objects. A measure of information associated with a system that can accept N possible states and is measured in bits. The equation of information is valid if the different states are equally probable [4]. If the different states are not exactly probabilistic, then the probability is considered as a weighted average. The first fairly clear proposals for ways to measure the amount of information date back to the early 20th century and belong to R. Fisher (in connection with the work on mathematical statistics) and

R. Hartley (in connection with the storage of information in storage devices) and its transmission through communication channels) [5]. The most common use in various fields of science and technology was the measure of information, which is formulated in the information theory of K. Shannon [6]. The theory is closely related to information entropy and uses mainly the mathematical apparatus of probability theory and mathematical statistics. From the standpoint of defining the concept of information in the system according to K. Shannon – "the system takes many equally probabilistic states".

The SI approach considers information as the ordering of many stationary states of a system. A priori information of the steady state of the system is characterized by many possible manifestations of the properties that are realized in its interaction with other systems (objects). Manifested properties of the steady state of the system are identified as a set of physical quantities of their values and uncertainties, which is the content of system information. Under external (internal) influence, the state of the system changes and a posteriori information captures the steady state of the system over time and the corresponding values of physical quantities and uncertainties. In physical space, the state of the system changes from the threshold of sensitivity to external (internal) influence. The influencing system also changes due to the fundamental properties of the universe of symmetrical "reflection". Traditional information analysis considers the transfer of information from the "transmitter" to the "receiver" is one direction from which side to look.

In technical-cybernetic systems, information has a parameter. A technical parameter is a physical quantity that characterizes any property of a technical device, system, phenomenon, or process. The number that characterizes this parameter (value) is its value. Nominal parameter (nominal value of the parameter) is its value, which is the beginning of the countdown of the actual and maximum tolerances. The parameter is characterized by the accuracy tolerance, which is laid down in the technical documentation for the object. Within the tolerance limits, the "information" of the parameter is not a change, its state is stationary. From the standpoint of the SI approach to defining the concept of the amount of information, the parameter has a finite value of possible stationary states and the number of these states is calculated as the logarithm of the ratio of the parameter value to its accuracy. In technical and cybernetic systems, "information" is laid down in the design and technological documentation. As a rule, in the finished product the amount of "information" is greater than the value of the coefficient of technological margin of accuracy $k_{ma} = 1,2-1,5$. Therefore, the quality of "information" received by the product during manufacture is relative, it characterizes the ratio of the amount of "information" embedded in the parameters of the product according to the technical documentation to the amount of inflated "information" parameters of the finished product: $I^{qual} = I^{td}/I^{fp} \cdot I^{td}$. The value of the "information" of the product is the result of the ratio of the number of parameters in the product according to the technical

documentation to the amount of "information" according to the technical documentation: $I^{\text{val}} = N^{\text{td}}/I^{\text{td}}$. The less information is spent on the parameter of the technical documentation without changing the functional characteristics of the product, the more valuable the product information.

In production, the tolerance of the accuracy of the parameter of the technical object is obtained due to the technological process of processing. The tolerance of the accuracy of the parameter is laid down and corresponds to the statistical principle of three standard deviations. The change of the content of the parameter information occurs when the parameter goes beyond the tolerance limit of the parameter accuracy.

Thus, the system-information approach allows to determine the amount of parameter information and record its change. From the standpoint of defining the concept of "information" of the object in the SI approach as "discrete-probability" (DP) information, the parameter takes many possible stationary states with respect to accuracy, and this ratio is a deterministic value for stationary stochastic systems.

The theoretical principles of the SI approach to the processes and systems of the technosphere are based on the fundamental properties of space – "reflection" [7]:

1) any elementary deviation from the nominal properties of objects in space and time entails many results of elementary "reflections" on other categorical attributes (general information connection of categorical attributes of properties of objects in space and time);

2) the elements of deviations of the "system of reflections" of the properties of objects are discrete in nature, they are the lowest thresholds of sensitivity to each other;

3) the discreteness of elementary deviations of space is due to the quantum nature of physical space;

4) the determinism of elementary deviations is due to the stationary in the period of discrete space of "mapping systems" of categorical attributes of the technosphere.

According to the theoretical principles of the SI approach, the mathematical model of a process or system parameter can be represented at two levels: the first as an element x (threshold of sensitivity) of the set of possible state X , which has a stochastic nature, and the second as a deterministic value of the ratio X/x the final value of the number of possible states of the system.

Thus, the content of such a model for measuring the parameter of a process or system is a set (unity) of the content of stochastic and deterministic parts, which determine the numerical value of possible states of a process or system relative to their sensitivity threshold and probability of transition from one state to another. The stochastic part of such a model carries information on the sensitivity threshold of the measuring parameter of the process or system, and the deterministic part carries the numerical value of the possible states of these parameters.

The theoretical component of the SI approach is based on the axiom and four laws of system-information communication of interacting objects and the methodology of SI modeling of processes and systems [7].

(Axiom). The change in the state of an object occurs as a result of external (internal) influence starting from the threshold of sensitivity of the state of the object to this influence.

1. Law No. 1 of identical DP reflection of information of properties of objects

$$I(x_i) = I(y_j).$$

2. Law No. 2 matching DP information properties of the reflection process

$$\log_2 \frac{\mu_A}{\sigma_A} = \log_2 \frac{\mu_B}{\sigma_B}, \quad \log_2 \frac{x_i}{\Delta x_i} = \log_2 \frac{y_j}{\Delta y_j},$$

where $\frac{\sigma_A}{\sigma_B}, \frac{\Delta x}{\Delta y}$ is a coefficient of information communication.

3. Law No. 3 additivity of DP information parameter properties

$$I_{y_j} = \sum_{i=1}^t I_{x_i}, \quad i = (1, t), \quad j = (1, k), \quad M_{y_j} = \sigma_{y_j} \cdot n^{i=1}.$$

4. Law №4 system properties of stationary DP information space

$$\sum_{i=1}^n I_{out}(s_i) = \sum_{j=1}^n I_{in}(s_j), \quad \sum_{ij=1}^n I(S_{ij}) = const,$$

where $S_{ij} \in s_{ij}$ are the interacting elements of a stationary system S_{ij} .

The theoretical foundations of the SI methodology for modeling the parameters of processes and systems of the technosphere are based on the "display" of DP parameter information (intensity), space (length) and time (duration). SI modeling considers fragments of reality of manifestation of objects of system which are combined in various configurations: intensity - duration; intensity - length; intensity - duration and length, within the homogeneity and variability of intensity, duration and length [7].

The discreteness of the state of properties is defined as the ratio of the values of the interval max (sup) and min (inf) of the manifestation of the intensity of the object, duration, length to the value of their lower limits of manifestation – the sensitivity threshold. SI models are structured without reference to the measurement scale. The logarithmic form of the SI model function with base $n = 2$ indicates the logarithmic law of information relations between objects, and the number of characters (complexity) required to record word information in the memory of a computing electronic device.

The threshold of "sensitivity" of the manifestation of the property by its nature has two boundaries of the interval lower and upper, within which the object information is not variable. For a stationary system, and technical-cybernetic systems are such within the parameter tolerance, the sensitivity threshold coincides with the accuracy tolerance limits, and the extended parameter uncertainty is within the tolerance range. From

the position of the SI approach, the technical-cybernetic system changes its state, ie information about itself when the value of the parameter exceeds the tolerance limits for accuracy.

For the first time the concept of uncertainty, as one of the directions of development of measurement, was proposed in the work of L. Finkelstein "Theory and Philosophy of Measurement" [8]. The reasons for the concept of uncertainty were the emergence of new non-traditional areas of measurement - analytical chemistry, psychology, sociology, pedagogy, medicine and more. The theory of uncertainty developed by scientists of the world led to the appearance of the document of the International Organization for Standardization ISO "Guide to Expression of Uncertainty in Measurement", published in 1993.

The uncertainty of the measurement result is characterized by either the average quadratic deviation (AQD) or symmetric boundaries, and the distribution of the uncertainty components by the evaluation method is divided into components of categories A and B [9]. The ISO governing document presents the definition of uncertainty – a parameter combined with the result of the measurement, characterizing the scattering of values of the measuring value.

Thus the DP information of a parameter is closely related to its value and uncertainty and is simultaneously both a deterministic and probabilistic characteristic of a physical quantity. In order to emphasize the difference between the units of measurement of DP information with the generally accepted notion of "information" (which is measured in bits), DP information is measured in discrete probability bits (DPbit).

The purpose of the work is to study non-traditional solutions to problems of technical-cybernetic systems on the basis of a system-information approach to the uncertainty of process parameters and systems of the technosphere.

Materials and methods of research

Estimation of parameters of technological processes and systems on the basis of system-information approach.

The values of the parameters are obtained directly from the results of physical measurements, data and / or other parameters and the form is mathematical formulas, so the information of the uncertainties of the arguments of the components of the formula are displayed on the information of the uncertainty of the function. At direct one-time measurements values of parameter are defined on indications of the device. The estimation of the value of the measured value is directly the display of the device, such estimation of uncertainty belongs to category B. At repeated measurements and statistical data processing the estimation of variance u^2 is characterized by the components received by estimation of type A. Data processing consists in the analysis of components of an error. In many cases, the measured value of Y is not measured directly, but determined from N other values of x_1, x_2, x_N by the functional dependence of $f(x)$.

SI methodology for estimating parameters is to estimate the value and uncertainty of the measured value of one "information object" based on the values and uncertainties of other "information objects" by implementing information laws, principles and algorithms performed on the SI measurement model.

The technological process is a cyclic stationary stochastic process in which the characteristics of the probability distribution with time shift do not change with each cycle.

The extended uncertainty interval is a random variable, but the process developed on the basis of experimental data is provided by parameter tolerances where the expanded uncertainty U of the measured quantity is within the accuracy tolerance range with a probability close to $TI \geq U$ regardless of the probability distribution law.

The tolerance values for the accuracy of the process and product parameters are normalized in the early stages of the product life cycle (LCP). They are functionally interconnected both in the production process and in the process of product operation.

The concept of SI methodology for estimating the parameters of the technological process is based on functional dependencies (1)

$$LM \rightarrow f_k(N_{pr}, TI_{pr}, N_{TE}, TI_{TE}, N_{TP}, TI_{TP}, mN_j, TI_j), \text{ at } TI \geq U, \quad (1)$$

where, LM – logarithmic measure of communication capacity of parameter, TI_{pr} (tolerance of accuracy of parameters of product), TI_{TE} (tolerance of accuracy of parameters of technological equipment), TI_{TP} (tolerance of accuracy of parameters of technological process), N_{pr} – parameters of product, N_{TE} – parameters of technological equipment, N_{TP} – process parameters, mN_j – other environmental parameters, TI – parameter accuracy tolerance, U – extended parameter uncertainty.

Functional dependences (1) form new principles for the development of a methodology for estimating the parameters of the technological process, the effective use of measurement information based on the development of the concept of the measure of communication capacity PQ.

Communication Capability (CC) of PQ is the potential ability of the properties of some objects to "reflect" on other objects discretely. It is a scalar quantity and is the only measure of the various forms of

communication of objects and is defined as $\frac{x_i}{\Delta x_i}$. The

logarithmic unit measure of communication capacity is defined as $\log_2 \frac{1}{\Delta x_i}$. The logarithmic measure (LM) of

communication capacity (amount of DP information) is defined as $\log_2 \frac{x_i}{\Delta x_i}$, where x_i is the value of PQ, Δx_i is

the sensitivity threshold. The measure of communication capacity is considered as a measure according to Lebesgue-Stieltjes [10].

Based on the Law №1 of the identical reflection DP of the property information and the Law №2 of the matching of the DP property information of the SI process, the model of the measuring parameter ("information" object y is a function of unrelated x) has the form

$$I(y) = \sum \log_2 \left(x_i \times \frac{1}{U(x_i)} \right), \quad U(x_i) \leq TI(x_i) = \Delta x_i, \quad (2)$$

if x is interconnected then the information model has the form

$$I(y) = \sum_{i=1}^n \log_2 \left(x_i \times \frac{1}{U(x_i)} \right) + \sum_{i=1}^n \log_2 \frac{1}{(U(x_i) - U(x_{i+1}))^2},$$

$$U(x_i) \leq TI(x_i) = \Delta x_i,$$

the parameter, Δx is the sensitivity threshold, $TI(x)$ is the accuracy tolerance, $1/U(x)$ is the unit measure of the communication capability of the parameter, $U(x)$ is the expanded uncertainty, and (y) is the amount of DP information measuring parameter.

The SI approach allows you to establish quantitative relationships between the evaluation of the measurement result and the uncertainty of the parameter. Provided that the extended uncertainty is equal to or less than the accuracy tolerance of the parameter $U(x_i) \leq TI(x_i)$, equation (2) has the form

$$\begin{aligned} \log_2 \frac{y}{\Delta y(U_y)} &= \log_2 \frac{x_1}{U(x_1)} + \log_2 \frac{x_2}{U(x_2)} \dots + \log_2 \frac{x_n}{U(x_n)}, \\ \log_2 \frac{y}{\Delta y(TI_y)} &= \log_2 \frac{x_1}{TI(x_1)} + \log_2 \frac{x_2}{TI(x_2)} \dots + \log_2 \frac{x_n}{TI(x_n)}, \quad TI(x_n) \geq U(x_n), \quad p=1, \\ \frac{y}{\Delta y(TI_y)} &= \prod_{i=1}^n \frac{x_i}{TI(x_i)}, \quad y = \Delta y(TI_y) \times \prod_{i=1}^n \frac{x_i}{TI(x_i)}, \quad \Delta y(TI_y) = \frac{y}{\prod_{i=1}^n \frac{x_i}{TI(x_i)}}, \\ TI_y &= k_y \times \Delta y(TI_y), \quad k_y = \frac{\sum_{i=1}^n TI(x_i)}{\prod_{i=1}^n TI(x_i)}, \quad TI_y \geq U_y, \quad u_c = \frac{U_y}{K}. \end{aligned} \quad (3)$$

where: u_c – total uncertainty, K – coverage factor.

The presented system-information algorithm for estimating the value of the parameter and the total uncertainty takes into account both the values of the standard uncertainties of the components of the formula and the values of the partial derivatives of these components.

We formulate the SI rule for estimating extended uncertainty: extended uncertainty of a measured quantity takes into account both the sum of values of extended uncertainties of functionally independent quantities, which does not contradict the generally accepted provisions [11], and the influence of components x_1, x_2, x_n on change y .

System-information methodology for estimating parameters is based on the use of three consecutive analytical methods.

Method 1. Methodology of SI modeling of measuring parameter of processes and systems.

It consists in the fact that the tolerances of the accuracy of the parameters of the technological system are interconnected both physically and on the basis of DP

information. That is, in the manufacture of products, the output of one parameter of the technological system beyond the tolerance of accuracy ultimately leads to the tolerance of the parameters of the part associated with it directly or indirectly. In the operation of a technical-cybernetic system, the departure of one parameter beyond the tolerance ultimately leads to the tolerance beyond the tolerance of other parameters directly or indirectly related to it.

The SI model of the parameter is based on the number of possible states of the parameter (a measure of communication capacity) as a system (in the information equation). This is the principle of equality of the sum of DP information of arguments and functions and is formalized as the logarithm of the ratio of the nominal value of the parameter to the uncertainty. For statistical DP, the PQ information is the logarithm of the ratio of the mathematical expectation to the standard deviation. The relative uncertainty is equal to the modulus of the inverse of the measure of communication capacity

$$\begin{aligned} \log_2 \frac{y}{\Delta y(U_y)} &= \sum_{i=1}^n \log_2 \frac{x_i}{U(x_i)}, \quad \delta(x_i) = \left| \frac{U(x_i)}{x_i} \right|, \quad \delta(y) = \left| \frac{\Delta y(U_y)}{y} \right|, \\ \log_2 \frac{1}{\delta(y)} &= \sum_{i=1}^n \log_2 \frac{1}{\delta(x_i)}, \quad \delta(y) = \prod_{i=1}^n \delta(x_i), \quad U_y = k_y \times y \times \prod_{i=1}^n \delta(x_i). \end{aligned} \quad (4)$$

This method uses the paradigm of relative errors because we study a technological system with constant values of tolerances on the accuracy provided by the technological process, and the uncertainty is within the tolerance of the accuracy of the nominal parameter.

$$\delta(a+b) = \frac{\delta a + \delta b}{|a+b|} = \frac{|a|}{|a+b|} \delta a + \frac{|b|}{|a+b|} \delta b, \quad \delta(a-b) = \frac{\delta a + \delta b}{|a-b|} = \frac{|a|}{|a-b|} \delta a + \frac{|b|}{|a-b|} \delta b, \quad (5)$$

$$\delta(a \times b) = \delta \frac{a}{b} = \delta a + \delta b, \quad \delta(a^k) = k \delta a.$$

Method 3. SI method for estimating the required and sufficient parameter accuracy.

The calculation method combines the use of two principles:

1) information modeling and 2) the method of estimating absolute and relative errors.

$$\log_2 \frac{y}{\Delta y(TI_y)} = \log_2 \frac{x_1}{TI(x_1)} + \log_2 \frac{x_2}{TI(x_2)} + \dots + \log_2 \frac{x_n}{TI(x_n)},$$

$$\log_2 \frac{1}{\delta(y)} = \log_2 \frac{1}{\delta(x_1)} + \log_2 \frac{1}{\delta(x_2)} + \dots + \log_2 \frac{1}{\delta(x_n)}, \quad \delta(x_i) = \frac{TI(x_i)}{x}, \quad \delta(y) = \frac{\Delta y(TI_y)}{y},$$

$$\frac{\Delta y(TI_y)}{y} = \prod_{i=1}^n \delta(x_i), \quad TI_y = y \times \prod_{i=1}^n \delta(x_i) \times k_y, \quad k_y = \frac{\sum_{i=1}^n \delta(x_i)}{\prod_{i=1}^n \delta(x_i)}. \quad (6)$$

Thus, in the generalized variant for $TI(y) \geq U(y)$ (6) there is an estimate of the necessary and sufficient accuracy of the parameter y due to the relative errors of the components within which there are relative extended uncertainties $U(x)$ regardless of the distribution law.

Equation (6) is an estimate of the extended uncertainty of the quantities due to the relative error for the known values of the uncertainties of the related quantities based on the DP information. If the values of the uncertainties of the related quantities are unknown, multiple measurements of the i -th parameter are used after each j -th cycle of the technological operation. To determine the i -th unknowns of the expanded uncertainty of the parameters, a matrix with the i -th rank is constructed. A relative scale is used to evaluate the result of the calculation of the unknown matrix. The choice of accuracy of the measuring instrument is provided by 10% of the interval of the calculated accuracy of the parameter.

Based on the equations of the SI approach, the following values are determined:

1) SI estimate of the value of the nominal parameter y_n without error;

$$\log_2 y_n = \log_2 x_1 + \log_2 x_2 + \dots + \log_2 x_n$$

$$y_n = 2^{\sum_{i=1}^n I(x_i)}, \quad (7)$$

2) SI estimate of the tolerance of $TI(y_n)$ at the given DP information x_i and the value of the nominal parameter y_n

Method 2. Methods for estimating relative errors.

If the relative error has a mathematical expression, then the principle based on the mathematical provisions of the relative error is used

If the interval of extended uncertainty $U(y)$ with the confidence level $p(y) = 1$ and is equal to the accuracy tolerance $TI(y)$, then we write SI equation (2) due to the relative error $\delta(y)$

$$\log_2 \frac{y_n}{\Delta y_n(TI_y)} = \log_2 \frac{x_1}{TI(x_1)} + \log_2 \frac{x_2}{TI(x_2)} + \dots + \log_2 \frac{x_n}{TI(x_n)}$$

$$\Delta y_n(TI_y) = \frac{y_n}{\sum_{i=1}^n I(x_i)}, \quad TI_y = \Delta y_n \times k_y, \quad k_y = \frac{\sum_{i=1}^n TI(x_n)}{\prod_{i=1}^n TI(x_n)} \quad (8)$$

3) SI estimate of the parameter Δy_n at the given tolerance of accuracy of $TI(y_n)$ and DP information x_i ;

$$\log_2 \frac{y_n}{\Delta y_n} = \log_2 \frac{x_1}{TI(x_1)} + \log_2 \frac{x_2}{TI(x_2)} + \dots + \log_2 \frac{x_n}{TI(x_n)},$$

$$I(x_i) = \log_2 \frac{x_i}{TI(x_i)}, \quad \frac{y_n}{\Delta y_n} = 2^{\sum_{i=1}^n I(x_i)}, \quad \Delta y_n = TI_y \times \frac{\prod_{i=1}^n TI(x_n)}{\sum_{i=1}^n TI(x_n)} \times y \quad (9)$$

Implementation of SI methodology for estimating the accuracy of measured values is based on the principles of DP information communication of process parameters and solves the following problems:

1) determines the accuracy with which it is necessary to measure the nominal parameter of the technological process to ensure maximum informativeness and quality of the result;

2) the analysis of the DP value of the information of the measurement result of the parameter, which provides indirect control of the associated parameters of the technological process for compliance with the uncertainty within the tolerances.

The use of the methodology of system-information approach to assessing the accuracy of measuring the parameters of the technological process and system ensures production efficiency, economical use of resources, identification and implementation of best practices, new equipment and production technology, prevention of unnecessary costs.

System-information methods and algorithms for effective use of discrete-probabilistic information in production.

System-information methods and algorithms for effective use of DP information are based on the scientific basis of the developed system-information approach as information technology, which from the standpoint of information principles provides accurate and timely, cost-effective assessment of controlled parameters and their required accuracy.

System-information approach as information technology is based on the developed scientific SI bases: method, method, means and process:

1) *method* – the theory of system-information approach to processes and systems;

2) *means* of application of the method - methodology of system-information modeling of processes and systems;

3) *means* of implementation of the method and method - information technology algorithms based on the logarithmic measure of the communication capacity of the controlled parameters;

4) the *processes* of collection, processing and use of discrete-probabilistic information of controlled parameters at the stages of the product life cycle.

The developed SI technology of effective use of discrete-probabilistic information of parameters formulates scientific positions of dependence between DP information of model of the controlled parameters of technological process and system, and production indicators.

1. Any method of production is displayed through the DP system of information of controlled parameters of production facilities.

2. The properties of the production object have the final numerical value DP of the information of the parameters that are the most objective characteristics of production.

3. The amount of DP information of the controlled parameters of the design documentation (DD), functionally related to the quantitative indicators of material, labor and energy resources for the production of the product. The object of the product is more economical in production, the smaller the numerical value of DP information of the parameters it has, which provide its official purpose –

$$\text{Costs (material, labor, energy)} = f(I_{DD}; I_S; I_{TP}).$$

4. Excess and loss of DP information of the controlled parameters of the product, technological system (TS), technological process (TP) are functionally related to the indicators of production quality in the system of information connections of the properties of production facilities -

$$\text{Quality} = f(I_{pr}, I_{TS}, I_{TP}, \Delta I_{exc}, \Delta I_{loss}).$$

5. The values of DP information of quantitative, qualitative and value evaluation of the manufactured product are functionally related to the indicators of production efficiency in the information communication system of production facilities involved in the technological process –

$$\text{Effect} = f(I_{val}, I_{qual}, I_{price}).$$

The algorithms for the effective use of technical and economic information of production are based on the proposed system of DP information controlled parameters relations which are presented in table 1.

The above algorithms are an element of the result of the corresponding measurements intended for use in the calculation formula KTI- (ISO 22400-2014).

Table 1. Methods of effective use of DP information

Indicators	Explanation
<p>1. Absolute (ALI), DP bit</p> $ALI_{DD} = \sum_{i=1}^k \log_2 \frac{x_i}{TI_i} = \log_2 \frac{1}{\delta(x_i)}, \quad ALI_{TP} = \sum_{i=1}^m \log_2 \frac{\mu_i}{S(x_i)} = \sum_{i=1}^m \log_2 \frac{1}{\delta S(x_i)}$ <p>where, x_i – the value of the measured value, TI_i – size tolerance, $TI_i \geq 3\sigma$, μ – mathematical expectation, δS – relative mean quadratic deviation.</p>	The amount of DP information of product parameters according to the documentation (DD), technological process (TP) and technological equipment (TE)
<p>2. Relative % (RLI)</p> $RLI_{DD} = \frac{ALI_{DD}}{ALI_{TP}}$	The ratio of absolute indicators of design documentation to the absolute indicators of the technological process shows the degree of excess or lack of resources expended
<p>3. Equivalent (ELI), DP bit, UAH</p> $ELI_{DD} = \sum_{i=1}^k \log_2 \frac{x_i}{TI_{x_i}} \div x_{pi} \times k(e_p / x_{pi}), \quad ELI_{TP} = \sum_{i=1}^n \log_2 \frac{\mu_{x_i}}{U_{x_i}} \div x_{pi} \times k_i(e_p / x_{pi}),$ <p>where – $k(e/x)$ – the coefficient of coordination of the controlled parameter to the energy E based on PL units, x_{pi} – PL unit</p>	The equivalent of the absolute energy consumption of the product based on the DP value of the information of the product parameters is equivalently recalculated using the coefficients of agreement on the DP value of the information of the unit of energy.
<p>4. Mixed (MLI), UAH/bit</p> $MLI_{DD}^o = \frac{KTI_o}{ALI_{DD}^o}, \quad KTI_n = MLI_{DD}^o \times ALI_{DD}^n$ <p>where, KTI – key technical and economic indicators, n – a new product, o – old product</p>	The equivalent recalculation of DP information is based on the use of "PL units".

2. Method of calculation of SI production indicators on the basis of acceptance statistical control.

2.1. The arithmetic mean value of the controlled product parameter

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}, \quad (10)$$

where n is a number of products.

2.2. The scope of scattering the qualitative characteristics

$$R_j = x_{\max} - x_{\min}. \quad (11)$$

2.3. Absolute actual logarithmic index of ALI_f

$$ALI_f = \log_2 \frac{\bar{x}}{R_j}. \quad (12)$$

2.4. Mixed actual logarithmic index MLI_f

$$MLI_f = \frac{KTI}{ALI_f}. \quad (13)$$

3. The parameter of production control (PC) is a change of processing process, change of processing methods, change of route, change of technological equipment

$$PC = \log_2 \frac{\bar{x}}{R_j} - \log_2 \frac{x_i}{TI_i} \rightarrow 0. \quad (14)$$

Development of methods using the methodology of SI evaluation of production characteristics in information measuring systems based on DP information allows us to contribute to the effective achievement of production management goals.

1. The method of calculating the absolute logarithmic index (ALI) of production is based on DP information of controlled parameters in the technical documentation and DP information of controlled parameters of receiving statistical control, which are used to control the level of process equipment for processing.

2. The method of calculating the relative logarithmic index (RLI) is used to control the parameters at the level of the technological process. The smaller the value of DP information of the parameters of the manufactured product with the same quality characteristics, the more perfect the processing technology. RLI indicators reflect the quality of the technological process.

3. The method of calculating the equivalent logarithmic index (ELI) is used to calculate the value of one discrete probable (DP) bit of the product, which is the most objective indicator with the same performance characteristics of the product. This ELI is used in the marketing, planning and accounting services of the company to assess the competitiveness of the product, as well as departments of R & D and product design. ELI indicators reflect the cost-effectiveness of technological resources for the product.

4. The method of calculating the mixed logarithmic index MLI is used to manage production at the enterprise

level. It allows you to compare the efficiency of different production units in terms of resource costs per discrete probable (DP) bit of the product on the CD. MLI indicators reflect the characteristics of the technological process used to predict the CRI of a new product in the technological preparation of new production.

When setting up a new product, the use of DP product parameter information allows in the early stages of the life cycle to predict the main technical, economic and production indicators required for technological preparation for the production of a new product, based on MLI production of the old product. This significantly reduces the time for technological preparation for the production of a new product and, as a consequence, improves the technical and economic performance of the enterprise.

On the basis of the presented methods of effective use of DP information methods of the decision of the following problems are developed.

1. Method of forecasting resource costs.

Provides KTI forecast of production in the early stages of the life cycle to optimize resource costs for technological preparation of production and production on the basis of LM product parameters according to the design documentation (DD) and technological documentation (TD) of production. Type of forecasting without development of technological processes: time of production of a product; energy and material waste for the manufacture of the product; labor-intensive manufacturing of the product; the level of automation of processes of this production; the level of quality of production processes; the level of optimization of technological processes of this or new production.

2. The method of optimizing resources in the preparation of production.

Provides optimization of resources of technological processes of manufacturing of a product and a choice of methods and parameters of management of technological process (TP) on the basis of DP of information of parameters of a product on DD and technological system (TS) of production.

3. Method of optimizing production management.

Provides control of product manufacturing parameters and optimization of control parameters of technological equipment in real time on the basis of DP information of product parameters on DD and TS of production.

4. Method of production efficiency control.

Provides analysis of DP values of information of controlled parameters of TP of production and DP of information of controlled parameters of finished products for identification of technological reserves of production resource.

An important principle of improving KTI production is the use of software in system-information measuring systems to solve problems of economic analysis at the levels of the shop, shop and production.

1. Perspective (forecast, preliminary) analysis of technical and economic indicators is used when launching a new product into production in the early stages of the

life cycle and is based on algorithms of absolute and mixed DP information of controlled parameters.

$$\frac{KTI_o}{ALI_{DD}^o} \times ALI_{DD}^n = KTI_n, \quad (10)$$

where o is a product that was manufactured earlier, and n is a new product.

2. Operational analysis is based on the use of data of statistical acceptance control of the product. This allows in real time the production time to calculate the change in the basic time of formation on the necessary parameters of the processing process to reduce the coefficient of technological margin of accuracy $CTMA = X \text{ const}/H_{\text{techn}}$ tends to one. Reducing the basic time for the operation in general in production increases productivity, reduces labor intensity and cost of the product.

3. The current analysis of the results of activities for a given period is used to identify technological reserves and is based on the comparison of actual production mixed indicators MLI, production with the values calculated on the basis of energy consumption for production on the technical documentation.

System-information principles and approaches to uncertainty based on "Planck units."

"Planck units" (PL units) are very far from the ranges used in practice and are not reproduced with the help of real physical objects, they define the limits of application of modern physical theories. Therefore, they are not used in metrology [12]. But the numerical values of "PL units" can be used in system-information analysis of process parameters and systems as the threshold of sensitivity (space-lp, time-tr, mass-mr, energy-Er, and so on) PQ. They are composed, calculated and interconnected through physical fundamental constants C (speed of light, m/s); \hbar (Dirac constant, J c); G (gravitational constant, m³/kg-1c-2) [13] and can be expressed one by one

$$l_p = \sqrt{\frac{G\hbar}{C^3}} \approx 1,616255(18) \times 10^{-35} \text{ m};$$

$$t_p = \sqrt{\frac{G\hbar}{C^5}} \approx 5,391246(60) \times 10^{-44} \text{ s};$$

$$m_p = \sqrt{\frac{C\hbar}{G}} \approx 2,176434(24) \times 10^{-8} \text{ kg};$$

$$E_p = \sqrt{\frac{\hbar C^5}{G}} \approx 1,9561 \times 10^9 \text{ J};$$

$$l_p = t_p C = \frac{\hbar}{m_p C}.$$

The rationale for the application of PQ "PL units" as a sensitivity threshold is that they are interconnected linearly with each other and with the FFC and their accuracy. In nature, the sensitivity threshold of PQ is the interval within which PQ does not change its DP information. The values of FFC and their relative accuracy were agreed by KODATA in 2002 [14] and are taken as constant values. From this point of view, the "PL units" of

PQ and their uncertainty are also constant values, and their DP information is constant over time. Therefore, the uncertainty of the "PL unit" can be used as a universal uncertainty PQ.

This approach makes it possible to calculate the equivalent values of "PL units" of PQ to each other.

We write the system-information equations for "PL units" l_p - space, t_p - time, m_p - mass, E_p -energy [15] to determine the extended uncertainty $U(l_p)$, $U(t_p)$, $U(m_p)$, $U(E_p)$ on the basis of SI provisions of the law No. 2.

For the logarithmic measure of PL length

$$l_p = \sqrt{\frac{G\hbar}{C^3}},$$

$$\log_2 \frac{P(l_p)}{U(l)} = \frac{1}{2} (\log_2 \frac{P(G)}{U(G)} + \log_2 \frac{P(\hbar)}{U(\hbar)} - 3 \log_2 \frac{P(C)}{U(C)}), \quad (11)$$

$$U(l) = \frac{l_p}{2^{\frac{1}{2}(\log_2 \frac{P(G)}{U(G)} + \log_2 \frac{P(\hbar)}{U(\hbar)} - 3 \log_2 \frac{P(C)}{U(C)})}}, \quad U(l_p) = U(l) \times k_p,$$

$$k_p = \frac{(U(\hbar) + U(C) + U(G))}{(U(\hbar) \times U(C) \times U(G))}.$$

For the logarithmic measure of PL time

$$t_p = \sqrt{\frac{G\hbar}{C^5}},$$

$$\log_2 \frac{t_p}{U(t)} = \frac{1}{2} (\log_2 \frac{G}{U(G)} + \log_2 \frac{\hbar}{U(\hbar)} - 5 \log_2 \frac{C}{U(C)}), \quad (12)$$

$$U(t) = \frac{t_p}{2^{\frac{1}{2}(\log_2 \frac{G}{U(G)} + \log_2 \frac{\hbar}{U(\hbar)} - 5 \log_2 \frac{C}{U(C)})}}, \quad U(t_p) = U(t) \times k_p.$$

For the logarithmic measure of PL mass

$$m_p = \sqrt{\frac{C\hbar}{G}},$$

$$\log_2 \frac{m_p}{U(m)} = \frac{1}{2} (\log_2 \frac{C}{U(C)} + \log_2 \frac{\hbar}{U(\hbar)} - \log_2 \frac{G}{U(G)}), \quad (13)$$

$$U(m) = \frac{m_p}{2^{\frac{1}{2}(\log_2 \frac{C}{U(C)} + \log_2 \frac{\hbar}{U(\hbar)} - \log_2 \frac{G}{U(G)})}}, \quad U(m_p) = U(m) \times k_p.$$

For the logarithmic measure of PL energy

$$E_p = m_p C^2 = \frac{\hbar}{t_p} = \sqrt{\frac{\hbar C^5}{G}},$$

$$\log_2 \frac{E_p}{U(e)} = \frac{1}{2} (\log_2 \frac{\hbar}{U(\hbar)} + 5 \log_2 \frac{C}{U(C)} - \log_2 \frac{G}{U(G)}), \quad (14)$$

$$U(e) = \frac{E_p}{2^{\frac{1}{2}(\log_2 \frac{\hbar}{U(\hbar)} + 5 \log_2 \frac{C}{U(C)} - \log_2 \frac{G}{U(G)})}}, \quad U(e_p) = U(e) \times k_p.$$

Let's calculate the numerical values of the logarithmic unit measure "PL units" for l_p - space, t_p - time, m_p - mass, E_p -energy and the order of absolute error, table 2.

Based on the calculated values of the logarithmic unit measure (LUM) of the basic units of the SI system, we calculate some values of the LUM for the derived units. Let's calculate the coefficients of adjustment Cad_j

(Er / PQp) as the ratio of Er PL energy to PQp PL physical quantity and enter them in table 3.

Table 2. Logarithmic unit measure of "PL units" (PQp)

Units of measurement PQ	Logarithmic unit measure PQp (LUMp) [DPbit]	The absolute error of the logarithmic unit measure PQp
Space (l) [1m]	$\log_2 \frac{1}{1,616 \cdot 10^{-35}} \approx 115,589$	$\Delta \approx 0,0097 \text{ m}$
Time (t) [1c]	$\log_2 \frac{1}{5,391 \cdot 10^{-44}} \approx 143,734$	$\Delta \approx 0,002 \text{ c}$
Substance (m) [1kg]	$\log_2 \frac{1}{2,176 \cdot 10^{-8}} \approx 25,454$	$\Delta \approx 0,0002 \text{ kg}$
Energy (E) [1J]	$\log_2 \frac{1}{1,956 \cdot 10^9} \approx -30,836$	$\Delta \approx 0,0002 \text{ J}$

Table 3. Logarithmic unit measure of PL units

No.	SI system units	Dimensionality	Logarithmic unit measure PQp [DP bit]	Coefficient of adjustment Cadj (Er / PQp)
1	Energy (Ep)	J = kg × m ² / s ²	-30,836	1
2	Substance (mp)	kg	25,454	-1,211
3	Space (Lp)	m	115,589	-0,267
4	Time (tp)	with	143,734	-0,215
5	Power (Rp)	kg × m ² / s ³	-174,57	0,177
6	Work (Ap)	kg × m ² / s ²	-30,836	1.0
7	The amount of heat (Qp)	4.1868J	-129,104	0,239
8	Pressure (pp-pascal)	kg / s ² × m	-377,603	0,082
9	Heat of combustion (Hp)	m ² / s ²	-236,56	0,13
10	Area (Sp)	m ²	231,178	-0,534

Example: Determine the equivalent value of power P to energy E in the system SI through PL units

$$\begin{aligned}
 E_p &= \sqrt{\frac{\hbar C^5}{G}}, \quad LUM(E_p) = \log_2\left(\frac{1}{E_p}\right), \quad LUM(P_p) = \log_2\left(\frac{1}{P_p}\right), \\
 P[\text{kg} \cdot \frac{\text{m}^2}{\text{c}^3}], \quad \log_2(P) &= \log_2(m) + 2\log_2(l) - 3\log_2(t), \\
 \log_2\left(\frac{1}{P_p}\right) &= \log_2\left(\frac{1}{m_p}\right) + 2\log_2\left(\frac{1}{l_p}\right) - 3\log_2\left(\frac{1}{t_p}\right), \\
 P_p &= \frac{1}{2^{(\log_2(\frac{1}{m_p}) + 2\log_2(\frac{1}{l_p}) - 3\log_2(\frac{1}{t_p}))}}, \quad C_{adj}(E_p / P_p) = \frac{LUM(E_p)}{LUM(P_p)}, \\
 \log_2 \frac{E_p^{eq}}{E_p} &= C_{adj}(E_p / P_p) \times \log_2 \frac{P}{P_p}; \quad E_p^{eq} = E_p \times 2^{(C_{adj}(E_p / P_p) \times \log_2 \frac{P}{P_p})}.
 \end{aligned} \tag{15}$$

where LUM(x_p) – logarithmic unit measure, E_p [J] – PL unit of energy, P_p – PL unit of power, E_p^{eq} [J] – PL energy equivalent to power in the system of units SI, C_{adj}(E_p/P_p) – coefficient of adjustment, P – power in the SI system.

Based on the Law №3. Affiditivity of information parameters of properties" of physical quantities and Cadj presented in table 3 you can calculate the amount of equivalent energy from the parameters that reflect the technical characteristics of the objects according to the formula

$$\begin{aligned}
 I &= \log_2 \frac{E_{xi}^{eq}}{e_p} = \sum_{i=1}^n \left\{ \log_2 \frac{x_i}{x_{ip}} \times C_{i(adj)}(E_p / x_{ip}) \right\} [DPbit] \\
 E_{xi}^{eq} &= e_p \times 2^{\sum_{i=1}^n \left\{ \log_2 \frac{x_i}{x_{ip}} \times C_{i(adj)}(E_p / x_{ip}) \right\}}, \\
 \sum_{i=1}^n E_{xi}^{eq} (techdoc) &= Ef_{prod} \cdot \sum_{i=1}^n E_{xi}^{eq} (techproc)
 \end{aligned} \tag{16}$$

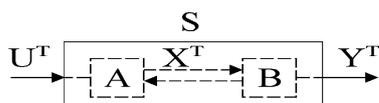
where $E_{\text{req}} [J]$ – PL equivalent of the parameter x_i to energy, x_i – parameters, x_{pi} – PL unit of the parameter, e_p – PL unit of energy, $C_{i(\text{adj})} (E_p / x_{ip})$ – coefficient of adjustment, $E_{f_{\text{prod}}}$ – effectiveness of production.

If we take into account (theoretically) all the properties of the object, or the performance of the product, the equivalent energy from the parameters of the object will be the most objective characteristic of its value. And given the cost of energy on the market at the moment, the price of the object will be tied to time. The ratio of energy

equivalent from the parameters of the product according to the design documentation to the equivalent energy from the parameters of the product as a result of the technological process, we obtain the efficiency of manufacturing the product. The system-information model of production formulates the principle of optimality which coincides with Pareto optimality: optimality is a state of some system in which the value of each particular indicator that characterizes the system cannot be improved without deteriorating others [16].

Use of system-information modeling in various scientific directions.

System-information modeling in systems theory.



- straightforward information process

$$S = U^T \sigma X^{T+1} \eta Y^{T+1}$$

$$\sigma: \{[T \times (T+1)] \times X^T \times U^T\} \rightarrow X^{T+1}$$

$$\eta: \{[(T+1)] \times X^{T+1}\} \rightarrow Y^{T+1}$$

U – enter

X – system status

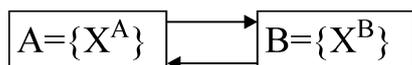
Y – exit

σ – transitive reflection

η – initial reflection

T – time

- cyclic information process



$$f: U^A(Y^B) \rightarrow X^A \rightarrow Y^A(U^B) \rightarrow X^B \rightarrow Y^B(U^A)$$

$$F(A, B) = U^A \sigma^A X^A \eta^A Y^A \theta U^B \sigma^B X^B \eta^B Y^B \nu U^A$$

$$X^A = \{X_i^A\}; X^B = \{X_j^B\}$$

$$\sigma^A, \sigma^B, \eta^A, \eta^B$$

ν, θ

$$U^A, U^B, Y^A, Y^B$$

$$\Omega = \sigma^A \eta^A \sigma^B \eta^B \theta \nu$$

- the set of system states

- reflection of initial and transitive systems A, B

- reflection of connectivity

- input and output of A and B systems

- total reflection of the system SAB

$$I[F(A)]: I(U^A \sigma^A X^A \eta^A) \rightarrow I(Y^A); I[F(B)]: I(U^B \sigma^B X^B \eta^B) \rightarrow I(Y^B);$$

$$I[F(A, B)]: I(Y^{A_T}) \rightarrow I(Y^{B_T}) \rightarrow I(Y^{A_{T+1}}); I(Y^A) = \{a_i\}; I(Y^B) = \{b_i\}$$

a_i, b_i – properties of the system S_A, B , T – time

System-information models of object dynamics.

$$1) F(y, \dot{y}, \ddot{y}, u, \dot{u}) + f = 0,$$

$$a_0 \ddot{y} + a_1 \dot{y} + a_2 y - b_0 \dot{u} - b_1 u - c_0 f = 0,$$

$$\Delta y = y - y^*, \Delta \dot{y} = \dot{y} - \dot{y}^*, \Delta \ddot{y} = \ddot{y} - \ddot{y}^*, \Delta u = u - u^*, \Delta \dot{u} = \dot{u} - \dot{u}^*, \Delta f = f - f^*$$

$y, \dot{y}, \ddot{y}, u, \dot{u}, f$ – expected values

$y^*, \dot{y}^*, \ddot{y}^*, u^*, \dot{u}^*, f^*$ – real values, Δy – interval,

$$a_0 \frac{\ddot{y}}{\Delta \ddot{y}} + a_1 \frac{\dot{y}}{\Delta \dot{y}} + a_2 \frac{y}{\Delta y} - b_0 \frac{\dot{u}}{\Delta \dot{u}} - b_1 \frac{u}{\Delta u} - c_0 \frac{f}{\Delta f} = 0,$$

$$2) \frac{\ddot{y}}{\Delta \ddot{y}} = S^{\ddot{y}}, \frac{\dot{y}}{\Delta \dot{y}} = S^{\dot{y}}, \frac{y}{\Delta y} = S^y, \frac{\dot{u}}{\Delta \dot{u}} = S^{\dot{u}}, \frac{u}{\Delta u} = S^u, \frac{f}{\Delta f} = S^f,$$

$S^{\ddot{y}}, S^{\dot{y}}, S^y, S^{\dot{u}}, S^u, S^f$ – communication capacity of quantities.

3) system-information equation of dynamics

$$\log_2(a_0 S^{\ddot{y}} + a_1 S^{\dot{y}} + a_2 S^y) = \log_2(b_0 S^{\dot{u}} + b_1 S^u + c_0 S^f) = 0.$$

$I(y, \dot{y}, \ddot{y}, u, \dot{u}, f)$ – the amount of information carried by the equation of dynamics;

4) DP information of differentiation of sum, product and share

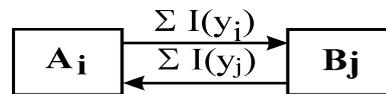
$$a) I\left(\frac{u}{\Delta u} + \frac{v}{\Delta v}\right)' = \log_2 \left(\frac{u'\Delta u - u\Delta u'}{\Delta u^2} + \frac{v'\Delta v - v\Delta v'}{\Delta v^2} \right),$$

$$b) I\left(C \frac{u}{\Delta u}\right)' = \log_2 \left(C \times \frac{u'\Delta u - u\Delta u'}{\Delta u^2} \right),$$

$$c) I\left(\frac{u}{\Delta u} \times \frac{v}{\Delta v}\right)' = \log_2 \left\{ \left(\frac{u}{\Delta u}\right)' \frac{v}{\Delta v} + \frac{u}{\Delta u} \left(\frac{v}{\Delta v}\right)' \right\} = \log_2 \left\{ \left(\frac{u'\Delta u - u\Delta u'}{\Delta u^2} \times \frac{v}{\Delta v}\right) + \left(\frac{v'\Delta v - v\Delta v'}{\Delta v^2} \times \frac{u}{\Delta u}\right) \right\},$$

$$d) I\left(\frac{u}{\Delta u} \times \frac{\Delta v}{v}\right)' = \log_2 \left\{ \left(\frac{u}{\Delta u}\right)' \frac{\Delta v}{v} + \frac{u}{\Delta u} \left(\frac{\Delta v}{v}\right)' \right\} = \log_2 \left\{ \left(\frac{u'\Delta u - u\Delta u'}{u^2} \times \frac{\Delta v}{v}\right) + \left(\frac{v'\Delta v - v\Delta v'}{v^2} \times \frac{\Delta u}{u}\right) \right\}.$$

System-information models of object management tasks.



$$\sum_{i=1}^n I(A_i) = f\left(\sum_{i=1}^n (I_{ni}; I_{yi}; I_{mi}; I_{R_i^n}; I(z_A))\right), \quad \sum_{j=1}^m I(B_j) = f\left(\sum_{j=1}^m (I_{mj}; I_{yj}; I_{mj}; I_{R_j^m}; I(z_B))\right)$$

$I(A_i), I(B_j)$ – system A, B status;

$I_{n,m}, I_{y_i,y_j}, I_{T_i,j}, I_{R_i,j}, I_z$ – properties (n, m), value (y), time (T), place (Rn), environment (z),

$$1. \sum_{i=1}^n I(A_i) = \sum_{j=1}^m I(B_j) \quad - \text{SI principle of management without loss of information.}$$

$$2. \sum_{i=1}^n I(A_i) - \sum_{j=1}^m I(B_j) = \sum_{i=1}^n \Delta I(B_j), \quad \sum_{i=1}^n \Delta I(B_j) \rightarrow 0 \quad - \text{SI regulation A} \rightarrow \text{B.}$$

$$3. \sum_{i=1}^n I(A_i) - \sum_{j=1}^m I(B_j) = \sum_{i=1}^n \Delta I(A_i), \quad \sum_{i=1}^n \Delta I(A_i) \rightarrow 0 \quad - \text{SI adaptation A.}$$

$$4. \left. \begin{array}{l} \sum_{i=1}^n \Delta I(A_i) \rightarrow \min(0) \\ \sum_{j=1}^m \Delta I(B_j) \rightarrow \min(0) \end{array} \right\} - \text{SI stabilization.}$$

$$5. \left. \begin{array}{l} \sum_{i=1}^n Q_i(A_i): \sum_{i=1}^n \Delta I(A_i) \rightarrow \min \sum_{i=1}^n \Delta I(A_i) \\ \sum_{j=1}^m Q_j(B_j): \sum_{j=1}^m \Delta I(B_j) \rightarrow \min \sum_{j=1}^m \Delta I(B_j) \end{array} \right\} - \text{SI self-organization.}$$

$Q_i(A), Q_j(B)$ – self-organization operators

$$6. \sum_{i=1}^n \Omega_{ij} \left(\sum_{i=1}^n I(A_i), \sum_{j=1}^m \Delta I(B_j) \right): \sum_{i=1}^n \Delta I(A_i) \rightarrow \sum_{i=1}^n I(A_i) \Bigg|_{\sum_{j=1}^m \Delta I(B_j) \rightarrow 0},$$

$$\sum_{i=1}^n \Omega_{ij} \left(\sum_{i=1}^n I(A_i), \sum_{j=1}^m \Delta I(B_j) \right): \sum_{i=1}^n \Delta I(A_i) \rightarrow \sum_{i=1}^n I(A_i) \Bigg|_{\sum_{j=1}^m \Delta I(B_j) \rightarrow 0}; \quad \Omega_{ij} \text{ operator (self) learning}$$

Discussion of results

Discussion of the results of this article should address several issues: 1) how the system-information approach corresponds to the principle of conformity in science?; 2) to what extent is the use of PL units in the

system-information approach as thresholds of PQ sensitivity justified?; 3) what principles of system-information approach can be used in different scientific directions.

The system-information approach is based on the concept of communication capacity. The value of

communication capacity quantitatively characterizes the ability of the quantity of information aggregation by quanta with other quantities. From the point of view of mathematics in the information equation the number of quantum quantities on the left side of the equation is equal to the number of quantum quantities on the right side of the equation. Communication capacity is quantified as the ratio of the value of a quantity to the interval of extended uncertainty of that quantity. If the interval of extended uncertainty is represented as the absolute error of the nominal value, then the value of such a modulo ratio is a quantitative characteristic of accuracy. This characteristic is used in engineering technology [17, p. 6].

1. System-information approach states that information has not only probable but also deterministic characteristics. All properties of the elements of the universe have DP information. The main properties of DP information in the system include the following:

- 1) the element that has DP information in the system is the value;
- 2) DP information of quantity, quality, value is the information characteristic of the state of the system;
- 3) the value of the interval of extended uncertainty of the elements within the system is a regular value;
- 4) in a balanced closed system with independent elements, the total DP information has a finite value and does not change over time;
- 5) in a closed system, increasing the interval of extended uncertainty of some elements leads to a decrease in the intervals of extended uncertainty of other elements of the system;
- 6) the amount of DP information in a closed system increases with the increase of interconnected elements of the system.

From the analysis of the properties of DP information in the system we can conclude that DP information behaves in the system as a Shannon negentropy. Its value is interrelated with the value of the interconnected elements, which are based on the sensitivity threshold of the system elements to each other. The value of DP negentropy is minimal for independent elements of the system and maximum for the overall interconnectedness of all elements.

Thus, DP information is a function of the value of the interval of extended uncertainty of the elements and the degree of their interconnectedness in the system. In a balanced closed system with independent elements of increasing DP information in one place, the system automatically reduces DP information in another place (analogous to the Pareto principle), as they obey the law of conservation of DP information as well as energy. The DP property of information self-organization of systems is based on this principle.

2. The use of PL units as sensitivity thresholds in determining the PQ equivalent to each other and to energy in units of the SI system is based on the same values of the amount of DP information possessed by PL units of mass, time and length. Since certain PQs, including energy, are derived from PL units of mass, time, and length, we calculated the matching coefficients on this basis and used them to calculate the PL equivalent of PQ to energy. It is

important that the PL units as the sensitivity threshold PQ can be considered as constant values due to the agreed values of the relative errors of the physical constants (KODATA in 2002).

3. Here are examples of the concept of using a system-information approach.

In cosmology: The universe is a multilayered, hierarchical DP information interconnected system in which the stabilization of elementary deviations of categorical attributes in time occurs on the principles of self-organization.

Self-organization of systems.

1) Self-organization of the system is one of the forms of organization which at the bifurcation point is independently structured (self-organized) without the involvement of external DP information resources.

2) In the process of self-organization, the structure of the system tends to a state of minimum DP information potential (the amount of DP information of the state of the system), which does not change its target functions.

3) The process of self-organization of systems is based on the principle of DP information coordination of uncertainty in the structuring (self-organization) of system elements.

The scientific provisions of the methodology of system-information approach explain a number of processes in various fields of scientific and economic activity.

In sociology: the level of development of society is estimated by the value of reaction time to changes in the uncertainty of the categorical attributes of the surrounding space in the self-organization of DP information links in society.

In economics: the level of economic development is estimated by the growth of DP information capacity of economic relations.

In the technosphere: technology is evolving in the direction of increasing the DP information capacity of products, and technology is evolving towards the growth of time-derived DP information capacity of manufactured products.

What are the prospects for the development of a system-information approach? We see in the development of DP-based models of computer technology to solve a variety of scientific and applied problems, especially software, which would replace experimental field tests of processes and systems with computer, by analogy with the scientific field of computer chemistry - computer physics, mechanics, engineering technology, etc.

What are the advantages of the proposed approach to modeling processes and systems of the technosphere?

1) DP models of processes and systems integrate elements of the product life cycle - due to the invariance in time of the information connection between them.

2) Simplifies mathematical methods of optimization in solving problems of analysis and synthesis of processes and systems - just choose a system with a minimum amount of DP information.

3) Reduces the cost of resources (similar to existing ones) in solving scientific and applied problems - computer, software, time, financial, etc.

Conclusions

The system-information approach to the uncertainty of the processes and systems of the technosphere makes it possible from a system-information point of view to look

at the patterns of development of the surrounding world and the laws of conservation. The methodology of its use provides an opportunity for non-traditional solutions to problems that have arisen in new areas of science and technology.

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СИСТЕМНО-ІНФОРМАЦІЙНИЙ ПІДХІД ДО НЕВИЗНАЧЕНОСТІ ПАРАМЕТРІВ ПРОЦЕСІВ І СИСТЕМ ТЕХНОСФЕРИ

Предметом дослідження в статті є системно-інформаційний підхід до невизначеності параметрів процесів і систем техносфери як один із наукових напрямків використання теорії інформації в метрології та інших наукових напрямків. В основі системно-інформаційного підходу лежить визначення поняття терміна "інформація" властивостей системи, її зміст і значення. Вирішення базового в метрології завдання отримання "інформації" кількісної характеристики істинного значення властивостей об'єктів і явищ, які розкривають закономірності навколишнього середовища, є складною науковою проблемою. Інструментом для отримання інформації про властивості системи є процес вимірювання. Один із напрямків розвитку теорії вимірювань є концепція невизначеності. **Мета** роботи – дослідження нетрадиційних рішень завдань техніко-кібернетичних систем на основі системно-інформаційного підходу до невизначеності параметрів процесів і систем техносфери. В статті вирішуються наступні **завдання**: провести аналіз оцінювання параметрів технологічних процесів та систем на основі системно-інформаційного підходу; розробити системно-інформаційні методи і алгоритми ефективного використання дискретно-імовірнісної інформації в техніко-кібернетичних системах; розробити принципи та підходи використання системно-інформаційної оцінки

невизначеності планківських одиниць, використання системно-інформаційного моделювання в різних наукових напрямках. Використовуються такі **методи**: системно-інформаційний підхід до процесів і систем, методологія системно-інформаційного моделювання вимірюваної величини; системно-інформаційна методологія оцінювання вимірюваної величини і невизначеності. Отримано наступні **результати**: розроблено системно-інформаційну методику визначення точності вимірювання номінального параметру, яка забезпечує максимальну інформативність непрямого контролю за пов'язаними з ним незалежними параметрами; розроблені системно-інформаційні алгоритми ефективного використання дискретно-імовірнісної інформації в техніко-кібернетичних системах; розроблено системно-інформаційну методику розрахунку планківського енергетичного еквіваленту технічних показників виробу; сформульований принцип розрахунку ефективності виготовлення виробу на основі планківського енергетичного еквіваленту фізичних величин. **Висновки**: Вирішення поставлених завдань дає можливість з інформаційного куту зору дослідити закономірності етапів життєвого циклу техніко-кібернетичних систем і закони перетворення і збереження.

Ключові слова: системно-інформаційний підхід; дискретно-імовірнісна інформація; невизначеність; планківські одиниці.

СИСТЕМНО-ИНФОРМАЦИОННЫЙ ПОДХОД К НЕОПРЕДЕЛЕННОСТИ ПАРАМЕТРОВ ПРОЦЕССОВ И СИСТЕМ ТЕХНОСФЕРЫ

Предметом исследования в статье является системно-информационный подход к неопределенности параметров процессов и систем техносферы как один из научных направлений использования теории информации в метрологии и других научных направлениях. В основе системно-информационного подхода лежит определение понятия термина "информация" свойств системы, ее содержание и значение. Решение базовой в метрологии задачи получение "информации" количественной характеристики истинного значения свойств объектов и явлений, которые раскрывают закономерности окружающей среды, является сложной научной проблемой. Инструментом для получения информации о свойствах системы является процесс измерения. Одно из направлений развития теории измерений является концепция неопределенности. **Цель работы** - исследование нетрадиционных решений задач технико-кибернетических систем на основе системно-информационного подхода к неопределенности параметров процессов и систем техносферы. В статье решаются следующие **задачи**: провести анализ оценки параметров технологических процессов и систем на основе системно-информационного подхода; разработать системно-информационные методы и алгоритмы эффективного использования дискретно-вероятностной информации в технико-кибернетических системах; разработать принципы и подходы использования системно-информационной оценки неопределенности планковских единиц, использование системно-информационного моделирования в различных научных направлениях. Используются следующие **методы**: системно-информационный подход к процессам и системам, методология системно-информационного моделирования измеряемой величины; системно-информационная методология оценки измеряемой величины и неопределенности. Получены следующие **результаты**: разработана системно-информационная методика определения точности измерения номинального параметра, которая обеспечивает максимальную информативность и качество результата измерения; разработаны системно-информационные алгоритмы эффективного использования дискретно-вероятностной информации в технико-кибернетических системах; разработана системно-информационная методика расчета планковского энергетического эквивалента технических показателей изделия; сформулирован принцип расчета эффективности производства изделия на основе планковского энергетического эквивалента физических величин. **Выводы**: Решение поставленных задач на основе системно-информационного подхода к неопределенности параметров процессов и систем дает возможность с системно-информационной точки зрения исследовать закономерности этапов жизненного цикла технико-кибернетических систем и законы сохранения.

Ключевые слова: системно-информационный подход; дискретно-вероятностная информация; неопределенность; планковских единицы.

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