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Analysis of forecasting parameters for technical objects

Abstract

The aim of the work is the development and research of parameters characterizing the process of functioning of a hybrid forecasting system oriented to use in technical object management systems. Parameters characterizing the process of its functioning have been developed and investigated in the paper.

Such parameters are relatedness and co-dimensionality, which characterize the consistency of the parameters of random events that negatively affect the technical object, with the parameters of counteracting this influence, which are formed within the framework of the forecasting system. A parameter has been developed that characterizes the degree of determinism of individual components of the system, which characterizes the amount of reduction in the degree of randomness of the obtained results of transformations implemented in the corresponding component. Also developed is the parameter of the measure of the countermeasure against the negative impact of a random process on a technical object, which is carried out by the corresponding component of the forecasting system, in the event of an external random event.

Thanks to the use of these parameters, it is possible to evaluate the key functions implemented by the forecasting system when it is used in management systems of technical objects and relevant technological processes.

Keywords: kinship, proportionality, consistency, determinism, counteracting negative influence.

Analiza parametrów prognozowania dla obiektów technicznych

Streszczenie

Celem pracy jest opracowanie i badanie parametrów charakteryzujących proces funkcjonowania hybrydowego systemu prognozowania zorientowanego do wykorzystania w systemach zarządzania obiektami technicznymi. W artykule opracowano i zbadano parametry charakteryzujące proces jego funkcjonowania.

Takimi parametrami są pokrewieństwo i współwymiarowość, które charakteryzują zgodność parametrów zdarzeń losowych negatywnie wpływających na obiekt techniczny z parametrami przeciwdziałania temu wpływowi, które kształtują się w ramach systemu prognozowania. Opracowano parametr charakteryzujący stopień determinizmu poszczególnych składowych układu, który charakteryzuje wielkość zmniejszenia stopnia losowości uzyskanych wyników przekształceń realizowanych w odpowiadającym im elemencie. Opracowano również parametr miary przeciwdziałania negatywnemu wpływowi procesu losowego na obiekt techniczny, realizowanego przez odpowiedni element systemu prognozowania, w przypadku wystąpienia zewnętrznego zdarzenia losowego.

Dzięki wykorzystaniu tych parametrów możliwa jest ocena kluczowych funkcji realizowanych przez system prognozowania, gdy jest on wykorzystywany w systemach zarządzania obiektami technicznymi i odpowiednimi procesami technologicznymi.

Słowa kluczowe: pokrewieństwo, proporcjonalność, spójność, determinizm, przeciwdziałanie negatywnemu wpływowi.

1. Introduction

In most cases, decisions about the need to use forecasting methods are made based on the analysis of various factors, which include data about the processes in relation to which they can be used, the nature of the problems for the solution of which a decision is made to use forecasting methods, and a number of other factors. In addition, there is a need to evaluate the effectiveness of the use of forecasting, which is mainly performed at the end of its current cycles. In general, methods of evaluating forecasting processes are based on the use of various analytical methods of analyzing the relevant processes. In order to implement such an assessment, in addition to the above approaches, it is advisable to analyze the capabilities of the selected forecasting system (SPG_i) solve the problems for which it is intended to be used. Such studies should be based on the results of the analysis of SPG_i parameters, their relationship with the features of the researched process and on the appropriate interpretation of SPG_i.

Forecasting in the classical interpretation is the process of determining the possibility of the occurrence of some event in accordance with the change in the value of the synchronizing parameter, which, in most cases, is time. We will call such forecasting synchronized. When it is necessary to predict the occurrence of some situation that may be caused by unforeseen events, then we can talk about situational forecasting. We will call the mechanisms of forecasting processes based on the use of extended methods of building hypotheses hypothetical.

Let's assume that forecasting is used to identify possible random events Vp_i that have a negative impact on the relevant technological processes TPr_i. Methods of using forecasting results Vp_i in control systems TPr_i allow different ways of their interpretation, examples of which can be the following descriptions.

1. Detection of the possibility of occurrence of unpredictable random events Vp_i and their causes.
2. By supplementing the forecasting system with means that provide expansion of its functional capabilities, the forecasting system turns into a hybrid forecasting system, which provides the possibility of expanding information about forecasted events.
3. The use of data obtained after the completion of a number of cycles of the forecasting process, for the implementation of the current cycle of the functioning of the forecasting system, allows solving problems related to the surrounding environment and technological processes.

The first description of the interpretation corresponds to the task of forecasting the selected event that may occur in the environment En_i in which TPr_i functions.

In the second case, it is possible to expand forecasting processes, which allows to connect it with solving other problems, for example, problems of protectioning TPr_i from dangerous events Vp_i, (Blanke, Kinnaert, Lunze, Staroswiecki, 2004). This approach to the interpretation of the prediction system SPG_i is quite common, as it allows expanding the capabilities of the SPG_i system itself (Resienkiewicz, 2019). This interpretation applies to hybrid forecasting systems, in which additional means of analysis can be used. The use of a hybrid approach to the creation of SPG_i makes it possible to more closely link the means of such a system and methods of forecasting with the features of the selected process TPr_i. This makes it possible to evaluate the parameters of the forecasting process and its effectiveness based on the data on the results of the impact on TPr_i of the processes on the part of SPG_i, which are aimed at counteracting the negative impact of Vp_i on TPr_i.

The third approach to the interpretation of SPG_i involves using the results of multiple prediction of events Vp_i with the aim of identifying patterns of their occurrence, as well as with the aim of using forecasting data to increase the accuracy of current forecasts.

In this work, the methods of analyzing the validity of the use of forecasting tools in the tasks of managing technical objects based on the determination of the values of the parameters characterizing them are investigated.

2. Parameters of the forecasting system

To determine the requirements for the SPG_i forecasting system, it is necessary to analyze the parameters that characterize it.

The characteristic that unites a group of two separate parameters, which are affinity and dimension, will be denoted by the abbreviation AD. The AD characteristic will determine the degree of consistency of the parameters used in SPG_i and TPr_i, which will be denoted by η_i. The given parameter types are described by the following definitions.

Definition 1. The affinity, which we will denote by η_i^a, means that the two compared parameters used in SPG_i and TPr_i are determined by the same natural factors, or have the same nature of interaction with the elements of $SUP_i(TPr_i)$, where SUP_i is the technological process control system TPr_i.

Let's assume that η_i^a can take the following limit values, which will be determined based on the analysis of factors affecting this value:

- $\eta_i^a = 0$ – means that the two compared parameters are not related, or do not have a common physical nature;
- 0<η_i^a <1 – means that the two compared parameters have differences in affinity;
- $\eta_i^a = 1$ means that the two compared parameters are related or have a common physical nature, the case when $\eta_i^a > 1$ is not considered.

There may be cases where the two selected parameters differ to some extent in their common physical nature. At the same time, they can interact, which depends on the magnitude of the degree of deviations of affinity between these two parameters (Gojda, 2013).

Definition 2. Proportionality, which will be denoted by η_i^d, means that the two compared parameters used in SPG_i and TPr_i are characterized by affinity and are measured by agreed measurement scales.

If two interacting parameters are related, but not commensurate, then in this case, an additional fragment of the technological process is designed, which would ensure commensurability of these parameters. There may be a case when such commensurability cannot be fully ensured for one reason or another. An example of such a reason can be undesirable redundancy in the implementation of TPr_i. In this case, partial redundancy is implemented in TPr_i, which is used only in case of occurrence of Vp_i. Such redundancy is activated by means of the system for counteracting the negative influence (SPW_i) of the event Vp_i on TPr_i, which is part of SPG_i. The range of values taken by η_i^d is determined similarly to the definition of η_i^a. The parameter η_i is a dimensionless value and is determined by the ratio:

$$\exists(\eta_i^\alpha = 0)[\eta_i = 0] \vee \exists(0 < \eta_i^a \leq 1)[\eta_i = \eta_i^a \cdot \eta_i^d] \vee \exists(\eta_i^a > 1)[\eta_i^a = \neg\eta_i].$$

The given characteristic can be used in various systems performing data analysis and transformation. The degree of inconsistency of the interacting parameters leads to errors in the analysis and calculation processes within the SPG_i system. If $\eta_i = 0$, it means that the calculations are performed with completely inconsistent systems SPG_i and TPr_i.

An important parameter for the SPG_i system is the degree of determinism of the processes implemented in the system components. The use of this parameter in forecasting systems is conditioned by the fact that in SPG_i one of the key components is the prediction component (SPB_i), which, by definition, cannot be considered deterministic (Billingslej, 2021). If we assume that the general purpose of using the SPG_i system is to achieve the necessary accuracy of predicting the values of the Vp_i parameters, then the degree of determinism of the components of the SPG_i system is a rather important parameter. We will denote this measure by $\lambda(\mathcal{K}_i)$, where $\mathcal{K}_i$ means the component of the SPG_i system, for example, the SPB_i component, the SWP_i component, or others. The measure λ takes into account the information component, which is a text description of the interpretation of the numerical component of the element $I_j(x_i^k) = j(x_i) * x_i$, where $j(x_i)$ is a text description of the interpretation of the variable x_i, which determines the numerical value of this component. The transformations $I_j(x_i^k)$ related to the determination of the value $\lambda(\mathcal{K}_i)$ concern not only the component x_i but also the component $j(x_i)$. The component $j(x_i)$ and the result of its transformations can change the interpretation of x_i and thus affect and determine the parameter λ (Li, Xia, Zong, Huang, 2009).

Let's assume that the determinism of some functional component will be determined by the amount of refinement of data or processes used in SPG_i. Such refinement is provided by the transformations used by the corresponding component and is also provided by the use of additional information by this component. The notion of determinism is quite general and, therefore, there is an opportunity to formulate various variants of interpretation of this concept. In this case, we will form an idea of the degree of determinism of the SPG_i component based on the following approach. The SPG_i system is focused on determining data about the random event Vp_i, on the basis of which it implements countermeasures against the negative impact of Vp_i on TPr_i. Therefore, determining the degree of determinism of the system SPG_i can be verified by the degree of elimination of the influence of Vp_i on TPr_i. In order to increase the value of λ, it is necessary to introduce additional components into the composition of SPG_i, which can provide such an increase. Consider the definition of determinism.

Definition 3. The degree of determinism $\lambda(\mathcal{K}_i)$ of some component $\mathcal{K}_i$ is determined by the amount of information expansion of the normalized text description of data interpretation, the amount of change in the value of this data and the amount of changes in other elements that are part of the information element $In_i(x_i)$, which, in sum, provides an increase in the degree of elimination of the influence of Vp_i on TPr_i. The value $\lambda(\mathcal{K}_i)$ can be described by the following relation:

$$\lambda(\mathcal{K}_\mathrm{i}) = \mathcal{K}_i^f [In(x_i^w) - In(x_i^v)] \, , (1)$$

where $In(x_i^w)$ consists of the following components: the magnitude of the input data values $h(x_i)$, the normalized description of the textual interpretation of these data $j(x_i)$, the amount of data change and other elements with their interpretation used in $\mathcal{K}_i$, $In(x_i^v)$ – represents a structure similar to $In(x_i^w)$, but refers to the information component at the output of the component $\mathcal{K}_i$, f – means the function describing the method of information expansion. The subtraction operator used in (1) means the method of determining the amount by which $In(x_i^j)$ increases.

The next parameter of the SPG_i system is the measure of the impact of forecasting results on the control object μ. The possibility of using the impact measure μ as a characteristic of SPG_i is indirectly related to the parameters η_i, λ_i and factors determined on the basis of the analysis of the interpretation of the ways of realizing the impact of SPW_i on $SUP_i(TPr_i)$, to which include the technical conditions that determine the possibility of implementation by the SPW_i component of counteracting the influence of Vp_i on TPr_i, and the consistency of the relevant technical means of object protection (SZO) of the system $SUP_i(TPr_i)$ with SPW_i.

Let us assume that TPr_i is implemented by a technical object (TO_i), which is partially characterized by the presence of its own resources Rv_i, which determine the possibilities of using the elements of TO_i, for the implementation of TPr_i and external resources (Rz_i), which determine the external materials and means necessary for the functioning of the process TPr_i and the production of products $\mathcal{P}\mathscr{p}_i$. For the production of $\mathcal{P}\mathscr{p}_i$, the process TPr_i uses the specified resources, due to which they decrease, raw materials in this case, we will not consider. If the negative factor Vp_i acts on TPr_i and TPr_i is not protected, then TO_i loses resources and may stop functioning completely. Protection of TPr_i from Vp_i can be done in different ways:

1. Only by using the SZO system.
2. By using the SZO system together with the transition of TPr_i to such operating modes, for the duration of Vp_i, in which the parameters that are not protected by *SZO* do not require protection because in the selected modes, they are affected by the parameters agreed with Vp_i s not essential.
3. The *SZO* system is not used, and TPr_i switches to operating modes for which the action of the corresponding parameters does not affect TPr_i for the during the action of Vp_i.

Let us introduce the definition of μ. *Definition 4.* The parameter μ of the measure of the impact of countermeasures against threats for TPr_i caused by the occurrence of Vp_i is determined by the ratio of the number of countermeasures provided by the SZO system to the sum of these countermeasures and countermeasures provided by the corresponding change in the operation modes of TPr_i. According to the definition, μ is calculated by the following expression:

$$\mu(Vp_i) = \sum_{j=1}^{k} V\left[SZO\left(x_j^*\right)\right] / \left\{\sum_{j=1}^{k} V\left[SZO\left(x_j^*\right)\right] + \sum_{r=1}^{g} V[TPr\,(y_r)]\right\}, \quad (2)$$

where $V\left[SZO\left(x_j^*\right)\right]$ – the measure of the countermeasure of the parameter with Vp_i, which is analyzed and transmitted by the component SPW_i to the SZO, for the protection of TPr_i, $V[TPr(y_r)]$ is the measure of the effect on the parameters of TPr_i, which are associated with the corresponding parameters x_j^* of Vp_i, but x_j^* do not affect y_r due to the fact that in the changed operation mode TPr_i, the parameters y_r cannot be vulnerable to x_j^*.

Parameter μ is used throughout the entire period of use of SPG_i with the system $SUP_i(TPr_i)$. The methods described above can be much more, since for the selection of the modes of operation TPr_i, situations can be selected in which the permissible decrease of one or the other type of resource is taken into account, or a change in the number of products during the time interval of the action Vp_i.

An important, integral parameter of the SPG_i system is the forecasting efficiency, π. This parameter is determined by most factors related to the system and uses parameters η_i, λ_i and μ_i. To evaluate the factors used by the parameter π, the notion of the measure of semantic significance of information (SI-signification of information) is introduced, which is represented by the elements of the textual interpretation description $j(x_i)$. The SI property of some $j(x_i)$ is determined based on the semantic analysis data of the corresponding $j(x_i)$. The following factors can serve as an example of characteristics that are components of efficiency.

1. The average number of detected negative events Vp_i during a given period, which is determined by the number of operation cycles TPr_i.
2. Significance of information obtained as a result of prediction and used to implement countermeasures against the negative influence of Vp_i on TPr_i.
3. The significance of the information provided by additional means and used in the formation of the process of counteracting the negative influence of Vp_i on TPr_i.
4. The average number of successful processes of prejudice to the negative impact of events Vp_i, which is implemented by SPW_i.
5. Characteristics of the input data necessary to predict the occurrence of the event Vp_i.
6. The value of the forecasting time interval ΔT_i of the event Vp_i and a number of other factors that may be related to the process of forecasting Vp_i.

Depending on the features of TPr_i, the forecasting system can be expanded with additional components focused on the use of specific features of the corresponding TPr_i. An example of such a feature can be the need to form a time trend of occurrence of Vp_i over a given number of cycles of TPr_i functioning. The second example of such a feature may be the need to assess the degree of threat to TPr_i from the influence of Vp_i on TPr_i, which is implemented based on the use of selected hazard criteria and others.

3. Determining the values of the parameters of the forecasting system

The parameter of forecasting efficiency, due to its universality, needs a more precise definition of the components characterizing it. From the above factors that determine efficiency, it appears that it can be divided into two parts. The first part is a generalized component of π^u, which can be determined from the data obtained during a number of performed forecasting cycles. The second part is the operational component π^τ, which characterizes the efficiency during one forecasting cycle. The factors determining π^u are described in points 1 and 4, and the factors determining π^τ are described in points 2, 3, 5 and 6. Depending on the need, in each individual case of using π^u and π^τ, the number of factors determining the corresponding efficiency components can be changed. The determination of the total value of efficiency can be calculated based on the ratio:

$$\pi = \pi^u(\Delta t_i) + \sum_{i=1}^{m} \pi_i^\tau, \text{ where } m = (1, 2, \dots, m).$$

The AD characteristic determines the degree of consistency of the parameters x_i and y_i interacting with each other, when the event Vp_i affects TPr_i. In many cases, there is a situation where the parameter x_i characterizing Vp_i indirectly affects TPr_i. Such mediation means that there are functional relationships between the parameters Vp_i and TPr_i, which ensure the necessary consistency according to the affinity parameter

η_i^α. Practically, the functional transformation $x_i^\alpha = f^\alpha(y_i)$ cannot provide complete affinity, where y_i is the parameter TPr_i, which interacts with the parameter x_i formed in SPG_i. To determine the value of the parameter η_i^α, the relation $\eta_i^\alpha = |y_i - x_i^\alpha|/y_i$ is used. The transformation $x_i^\alpha = f^\alpha(y_i)$ is preferably implemented within the framework of the technical object in which the corresponding process TPr_i functions and is formed on the basis of the physical interpretation of the corresponding parameter.

The next component of this group is the proportionality parameter η_i^d. It is defined by the relations: $[\aleph(y_i) = \aleph(x_i)] = (\eta_i^d = 1)$, where $\aleph$ is the scale in which y_i and x_i are measured. If there is a situation where $[\aleph(y_i) < \aleph(x_i)]$, then the scale alignment ratio $[\aleph(y_i) < \aleph(x_i)] \rightarrow [x_i^d = f^d(y_i)]$, where $f^d(y_i)$is the corresponding scale equalization function, which is set when designing protection means in TPr_i. Such alignment is carried out in the direction of a larger scale. This means that TPr_i should not receive the impact value x_i, which is significantly greater than the permissible impact value, which can lead to the destruction of TPr_i. Therefore, the protection system TPr_i activates additional means of protection to counteract the influence of x_i on TPr_i, the countermeasures of which are increased to the necessary extent. These tools are implemented within the framework of TPr_i. The value of the parameter η_i^d is determined by the relation: $\eta_i^d = (|y_i - x_i^d|)/y_i$. In the case where the relation: $[\aleph(x_i) < \aleph(y_i)] \rightarrow (\eta_i^d = 0)$ is present, the value of x_i is not large enough to effectively influence y_i and consistency is not considered.

The next parameter of the components of the SPG_i system is the measure of their determinism $\lambda(\mathcal{K}_i)$. Let's accept the restriction that the information elements used to determine $\lambda(\mathcal{K}_i)$ consist of two parts. The first part is $j(x_i)$ – a textual description of the interpretation of the variable x_i. The second part is $j(x_i)$ is the value of the number x_i. Textual descriptions are implemented based on the use of ideas about semantic dictionaries Sc_i, which are formed for separate subject areas, which consist of TPr_i and En_i.

Text components are normalized texts that are formed only from phrases presented in Sc_i. For the formation of each segment of the text, defined grammar rules of the corresponding language are used. The component $j(x_i)$ describes the textual interpretation of the number x_i, which describes the possibilities of its use within the framework of the SPG_i system. An information element can be written in the form:

$$In(x_i^v) =< a_1, a_2, \ldots, a_n >*< x_i >,$$

where a_i is the phrase of component $j(x_i)$, x_i is the value of the variable. Semantic parameters are used in order to be able to enter numerical estimates in the analysis of textual descriptions (Matsuo, Ishizuka, 2004; Liu, Yu, 2005). In Sc_i, each element, which is a separate phrase of the text, is assigned a semantic significance $\sigma_i^z(\alpha_i)$, which is determined based on the analysis of the subject area $Q = \{En_i, TPr_i\}$. Two adjacent phrases in $j(x_i)$, for example, $<\alpha_i * \alpha_j >$ are characterized by semantic consistency σ_i^u, which is determined by the relation $\sigma_i^u = \left|\sigma_i^z(\alpha_i) - \sigma_i^z(\alpha_j)\right|$. Based on the analysis of Q, the permissible ranges of values for σ_i^u are determined. Similarly, the limit values of σ_i^u for adjacent sentences are determined. The amount of information expansion is determined by the number of phrases with which $j(x_i)$ was expanded, taking into account the values of σ_i^u. The transformation of texts, which is implemented when using formula (1), is implemented by means of text transformations. The purpose of these transformations is to determine the magnitude of the expansion $In(x_i^v)$ (Korostil, Korostil, 2012).

The parameters of the event Vp_i are used to determine the degree of necessary counteraction to such an effect on TPr_i, which is carried out using SPW_i.

To calculate the value μ, the component SPW_i uses the simplified process model TPr_i, which is placed in SPR_i. This model takes into account the values of the following elements: the external resource Rz_i and the internal resource Rv_i, the amount of products $\mathcal{P}\mathscr{p}_i$ produced by TPr_i. The quantity μ is dimensionless and is determined by the following limiting values. The maximum value of this parameter $\mu = 1$ corresponds to the situation when the corresponding parameters in TPr_i are selected for all parameters of the event Vp_i and the influence of Vp_i on TPr_i is counteracted using SZO protection tools. In this case, the influence of Vp_i on TPr_i is completely eliminated and it does not lead to additional changes in TPr_i resources. The minimum value $\mu = 0$ corresponds to the situation when the SZO system is not used. In this case, the influence of Vp_i on TPr_i is eliminated by transferring the technological process to a mode in which the parameters of Vp_i do not affect the technological process. This is possible due to the situation when the parameters of TPr_i, which is related to the parameters of Vp_i, are not used in TPr_i, or their values are much larger than the related parameters of Vp_i, which is provided by the selected operating mode TPr_i.

The parameter μ, according to the formula (2), determines the ratio of the number of pre-emptive countermeasures $V\left[SZO\left(x_j^*\right)\right]$ to the sum of $V\left[SZO\left(x_j^*\right)\right]$ and quantities $V[TPr(y_r)]$, which we will also call operative counteraction. Of course, preemptive counteracting of attacks is much more effective compared to operative counteracting, which is implemented in the real-time operation mode $TPr(y_r)$. The SPW_i system implements all algorithms counteracting the implementation of $V\left[SZO\left(x_j^*\right)\right]$, and in the case of $V[TPr(y_r)]$ takes part in counteracting the negative impact of Vp_i together with the systems controlling the technological processes of functioning TO_i. From this it follows that the dependence of copper on the parameters μ and the SPW_i system will not lead to a decrease in the measure of counteracting the negative influence of Vp_i in an uncontrolled manner.

The magnitude of influence μ, which characterizes the component SPW_i acting on TPr_i, also depends on the value and number of parameters Vp_i, to counteract which it is necessary to use means of countering the negative influence of Vp_i on TPr_i. Thanks to the use of the μ parameter, it is possible to determine the required number of countermeasures against events Vp_k, which may be similar to Vp_i on successive cycles of functioning $SUP_i(TPr_i)$. By increasing the rate of change of μ, it is possible to determine, for example, the possibility of dangerous situations in $SUP_i(TPr_i)$.

Information about the prediction time period Δt of the occurrence of Vp_i is needed by the SPW_i component. This information allows you to monitor the possibility of fulfilling the following conditions:

- the amount of time for predicting the moment of occurrence of Vp_i and the process of implementing counteraction $SPW_i(x_i^*)$ of the influence of Vp_i on $TPr_i(y_i)$ should not go beyond the prediction interval ΔT_i;
- within the time limit ΔT_i component SPW_i should prepare the processes of biasing the impact of Vp_i on TPr_i, if it turns out that it is possible, and the implementation of a number of other processes that may be associated with the specific features of TPr_i and the requirements of the forecasting goal.

Additional means used within the SPG_i system can be divided into the following types:

- means that can be used to implement the processes of counteracting the influence of Vp_i on TPr_i;
- means that implement additional functionality to expand information that is necessary for the formation of prejudice processes or processes of counteracting the influence of Vp_i on TPr_i.

Consider additional means of the second type, an example of which is a component or a decision-making system (SPR_i). This component is intended to implement the corresponding information extension of the data received from SPB_i by the SPW_i component. When using advanced information, the SPW_i component can implement a more effective countermeasure against the influence of Vp_i on TPr_i. The capabilities of the SPR_i component, in each individual case, are determined by different requirements. Known representations of components of type SPR_i are quite developed and have different interpretations (Chakravorty, Ghosh, 2009; Turban, 1995). Examples of the functionality of the SPR_i component can be the following functions:

- if necessary, the SPR_i component can calculate the data received from SPW_i, the values of which it can use to form recommendations for the implementation of countermeasures;
- if the choice of a solution for SPW_i depends on the parameters formed in SPB_i and on the factors characterizing $SUP_i(TPr_i)$, then the necessary dependencies are formed in SPR_i, based on the use of which corresponding recommendations are formed, which are transferred to SPW_i and others.

The SPR_i component can contain information about $SUP_i(TPr_i)$ and about the means and processes of countering the influence of possible Vp_i, if they are provided in TPr_i. The SPW_i component determines countermeasure processes taking into account the information received from SPB_i. Thanks to the use of SPR_i, the SPG_i system becomes more versatile, and its adaptation to a separate TPr_i consists in implementing additional functionality and data in the SPR_i component.

4. Organization of the process of functioning of system components prognostication

The organization of the forecasting process SPG_i can be implemented in various variants, which differ from each other using additional components, taking into account individual event parameters Vp_i and others. Let's consider the possible organization of SPG_i work using the given parameters and tools. We will not describe in detail how to use all parameters and factors. Let's consider the organization of the functioning of individual components of the system.

The input data needed to implement the prediction of the random event Vp_i must be adapted to the component SPB_i. The event Vp_i is such a deviation of the value of the parameter of the external factor, which is Vp_i, which has a negative effect on TPr_i. The event Vp_i is generated by the process $Pr_i[En(Vp_i)]$, which is implemented in the En environment in which TPr_i functions. Such an event means that an unacceptable deviation of the parameter that characterizes Vp_i in $Pr_i[En(Vp_i)]$ has occurred. Such a deviation occurs as a result of an accelerated change in the value of the corresponding parameter. Therefore, the initial data $\{\xi_0, \xi_1, \dots, \xi_n\}$ about such a process must be ordered in relation to the selected synchronizing parameter. Such a parameter is time intervals written in the form $\Delta t_i \in \Delta T$. Since the occurrence of Vp_i is determined by the acceleration with which the values of ξ_1 change, the input data must be replaced by their differences between adjacent parameters: $x_i = |\xi_{i-1} - \xi_i|$. Then, you can write the input data in the form: $\{x_1, \dots, x_n\}$ and, to implement the prediction, we will use them as variable values of the parameter characterizing the process $Pr_i[Vp_i(x_i)]$. Consider the following statement.

Statement 1. If the set of variable quantities $\{\xi_1, \dots, \xi_n\}$, which are the initial data used for forecasting, have a common feature β, based on which they are combined into the corresponding set Ξ_k, then there exists a function of the increments of these quantities, which can be represented in the form:

$$\vartheta = \chi(x_1, \dots, x_n),$$

where $\{x_1, \dots, x_n\}$ are independent variables for which $x_i \in X_k$, t_i is a synchronization parameter, ϑ is a dependent variable of a function that can be extrapolated.

The function ϑ is formed based on the use of variables $x_i \in X_k$. Synchronized forecasting provides the possibility of ordering the values $\{x_1, \dots, x_n\}$ in such a way that they are associated with the parameter t_i. If we assume that the function $\vartheta = \chi(x_1, \dots, x_n)$, is discrete, then it exists, by definition, since $\{x_1, \dots, x_n\} \in X_k$ and the place $x_i = |\xi_i - \xi_{i+1}|$, where $\{\xi_1, \dots, \xi_n\}$ are the initial data. If the ordered set ξ_i represents a function with discontinuities, then the discontinuity points are constant and therefore predictable. Discontinuity points in $\phi(\xi_i)$ can be located only within intervals of type $\xi_i - \xi_{i+1}$. Since ξ_i and ξ_{i+1} are numbers obtained on the basis of their registration or from other sources, the function $\vartheta = \chi(x_1, \dots, x_n)$ can be interpreted as pseudo-continuous. The breakpoints in $\phi(\xi_i)$ are constant and known, if the function values at these points cause a negative impact on TPr_i, then in TPr_i protection against their influence is assumed. The function, which is built on the variables determined by the differences between successive values of the initial data $\{\xi_1, \dots, \xi_n\}$, is a function $\vartheta = \chi(x_1, \dots, x_n)$ that can be extrapolated and used to implement prediction processes.

In the process of preliminary analysis of the initial data, the prediction time is determined. The information about the expected event includes, at a minimum, the following data: the values of the parameters characterizing Vp_i, the time interval during which the expected event may occur.

Let's accept the hypothesis that the predicted event Vp_i must be known to some extent by $SUP_i(TPr_i)$ and, as a result, by SPG_i. A characteristic feature of SPG_i, for cases when they are oriented to service $SUP_i(TPr_i)$, is their functional orientation to the corresponding object (Tetlock, Gardner, 2017). Prediction results from SPB_i are transferred to component SPW_i. The initial information about Vp_i, which is known, is used by the SPB_i component and placed in the SPR_i component. Since the component SPW_i provides the possibility of using data about the expected event, it implements the management of the reaction process of the SPG_i system to the possible impact of Vp_i on $SUP_i(TPr_i)$. This part of the process can be of two types: the first type of process is related to the implementation of preventing the influence of Vp_i on the object, which will be denoted by the symbols $Pr_i(PWz_i)$ and the second type of process is related to the implementation of counteracting the influence of Vp_i we will mark the object as - $Pr_i(PWd_i)$ (Cedro, Wilczkowski, 2018).

The process $Pr_i(PWz_i)$ enables the protection system of the SZO object to activate the processes of prejudging the possibility of the influence of Vp_i on $SUP_i(TPr_i)$. The process $Pr_i(PWd_i)$ enables the SZO system to activate the processes of counteracting the possibility of the influence of Vp_i on $SUP_i(TPr_i)$. The use of the first or second type of reaction processes for predicting the occurrence of the event Vp_i depends on the following factors. The first factor is determined by the time interval required for the preparation of protective equipment in the SZO system, which is part of the SUP_i system of the corresponding TPr_i. During the time indicated by the process $Pr_i(PWz_i)$ and determined by the time interval $\Delta\tau_i$, the SZO system performs the processes of preparing the SZO system to counteract the influence of Vp_i. This time interval depends on the time required by the SPW_i component to perform data preparation procedures for their transmission to the SZO system. This is due to the fact that SPW_i may require additional data or calculations performed in the SPR_i component, and from the prediction period, which is determined by the SPB_i component and depends on the complexity of the prediction process. This interval also depends on the transition speed of the anomaly in En_i into a random event Vp_i. From the SZO side, after its activation by the process $Pr_i(PWz_i)$, it is necessary to set the values of the parameters of the corresponding protection means to those that correspond to the values of the parameters of the impact on them of the corresponding event Vp_i.

In case of activation of the process $Pr_i(PWd_i)$, the SZO system in real time, determined by the speed of implementation of the impact process Vp_i, provides the necessary value of the countermeasure against the corresponding impact. The case when it is necessary to activate the countermeasure of Vp_i on $SUP_i(TPr_i)$ is less desirable. To avoid this, it is possible to increase the amount of information about possible events Vp_i, which would reduce the time for calculations performed in the component SPR_i. This problem can be solved by two approaches that complement each other. Such approaches are based on the following hypothesis.

Hypothesis 1. Types of different events Vp_i in environment Q can be repeated and there is a possibility to determine the probability of such repetitions.

The first approach is to accumulate data about different Vp_i in the component SPR_i. When recognizing another event Vp_i, which has already occurred in the past, or is sufficiently similar to it, the SPW_i component can use ready-made data that have been calculated or used in appropriate cases. This approach requires recognition of the current event Vp_i by the system SPW_i (Lin, 2007).

The second approach is more effective and consists of the following. The SPB_i component is extended by additional functions that implement the prediction of the possibility of occurrence of Vp_i events of a certain type in the next case. In this case, we are not talking about the complete identity of the two events, since they may differ in the values of the parameters characterizing them. The similarity of two different events is determined in the following way.

Definition 4. Two random events Vp_i are similar if, to counteract their impact on the object $SUP_i(TPr_i)$, the same type of countermeasures are used in the SZO system.

The next component of the SPG_i system is the SPR_i component. The SPR_i component contains data and function implementation algorithms necessary for the successful implementation of $SUP_i(TPr_i)$ protection against the negative influence of Vp_i. These include the following data, functional components and other information:

1. Information about defenses aimed at countering threats that Vp_i can form.
2. Algorithms for determining current values of parameters characterizing the forecasting system.
3. Information on previous forecasting cycles and data on implemented protection processes TPr_i from Vp_i, which can be used in current cycles of forecasting process implementation.
4. Information about the environment in which TPr_i functions and is the immediate environment of the protection object En_i.
5. Components necessary for the analysis and transformations of textual descriptions of the interpretation of system elements, for example $j(x_i)$, and other additional textual information necessary for the implementation of counteraction processes.
6. Additional functional tools necessary for the implementation of forecasting processes.
7. Means of storage and formation of data about the parameters of the SPG_i system and the threats that were foreseen by the forecasting processes.

The SPR_i component is used within the framework of the SPG_i system as an auxiliary tool in the implementation of the process of forecasting and countermeasures against the influence of Vp_i on TPr_i. The SPR_i system is one of the components, the use of which allows increasing the value of the parameter of the degree of determinism of the SPW_i component and the SPB_i component. This leads to an increase in the value of the influence measure parameter SPW_i on TPr_i. The conditional scheme of the influence of the system SPW_i on TPr_i with the aim of counteracting the negative influence of $Vp_i(x_i)$ on TPr_i can be written in the form:

$$Vp_i(x_i) \to SWP_i(x_i^*), \text{ where } x_i^* = \psi[x_i, x_i^r, x_i^p(\lambda, \eta)],$$

where x_i^r – information obtained from SPR_i, x_i^p is a variable that characterizes the influence of parameters λ, η on x_i. The SPW_i system largely performs intermediate functions between the SPB_i component and $SUP_i(TPr_i)$ using the SPR_i component. Therefore, the autonomy of its functioning, in comparison with the SPB_i component, is significantly smaller.

A certain degree of affinity between the parameters Vp_i and TPr_i is ensured at the design stage of TPr_i. Since TPr_i functions in the environment of En_i, the process of $Pr_i(TPr_i)$ must involve the interaction of its own characteristics with the parameter's characteristic of En_i, where the processes of $Pr_i(Vp_i)$.

An important characteristic that determines the degree of agreement between Vp_i and TPr_i is the AD characteristic consisting of two parameters: affinity and co-dimensionality. The affinity parameter can change if fragments of other environments appear in the surrounding environment. This case requires separate research. Therefore, we will assume that the affinity parameter is within acceptable limits. The parameter of commensurability is analyzed in cases where the commensurability of two parameters is the same and in the case when there is a relationship: $[\aleph(x_i) > \aleph(y_i)] \to [x_i^d = f^d(y_i)]$. The possibility of using such a ratio in relation to a separate parameter is provided in the design process TPr_i. The implementation of a change in the value of this component can change the component of the matching parameter.

The measure of determinism λ is more complicated, as it is determined within the framework of transformation processes performed by one or another component. This parameter, unlike the η parameter, is not a constant characteristic, but depends on the conditions of the transformation process and on the data itself, which are subjected to such transformations. For example, the SPR_i component can consist of a number of transformation algorithms determined by the corresponding problems that need to be solved. Each individual algorithm with SPR_i, depending on the input data and the requirements for the method of their transformations, can form different values of the value of λ. The transformations implemented by the SPR_i component consist of two parts. The first part carries out mathematical transformation of numerical values (functional, logical, combinational or other). The second part performs the transformation of the textual descriptions of the interpretation of the corresponding data [$j^d(x_i)$] using the textual descriptions of the interpretation of the general principle of transformations performed by this algorithm [$j^a(l_i^x)$]. As a result of semantic transformations of these interpretations, we get a textual description of the interpretation of the obtained result, which, by definition, consists of a larger number of semantic elements, which are phrases. Formally, such a transformation can be described by the relation:

$$j_i^R(x_i^* * l_i^x) = \mathcal{F}\{j^d(x_i), j^a(l_i^x)\}, \quad (3)$$

where $j_i^R(x_i^* * l_i^x)$ description of the textual interpretation of the result of semantic analysis and transformation of two components, which are $j^d(x_i)$ and $j^a(l_i^x)$. The description of the transformation process (3) in an explicit form requires the use of a textual semantic analyzer (Jurafsky, Martin, 2009).

For each transformation of numerical values of variables $x_i \rightarrow x_i^*$, transformations of their textual interpretations describing the corresponding variables are performed. These text transformations are implemented in accordance with the rules that provide changes in the size of the text description of the interpretation of the obtained result. Such changes lead to an increase in the size of textual descriptions of the result of transformations. The corresponding increase in the final version of the text description $j_i^R(x_i^* * l_i^x)$ in relation to $j^d(x_i)$ and $j^a(l_i^x)$ occurs due to the following factors. The increase occurs due to the use of additional data related to the forecasting object and located in SPR_i and due to the expansion of the semantic value $j^d(x_i) \rightarrow j^a(l_i^x)$, which occurred due to the use of the functional transformation $x_i \rightarrow x_i^*$.

5. Conclusions

The work examines the parameters characterizing the processes that occur in the hybrid forecasting system. The use of the proposed parameters makes it possible to evaluate the effectiveness of the forecasting process based on the obtained results, which ensures the protection of technological process from the influence of random non-negative events. When using the proposed parameters, it becomes possible to increase the efficiency of using forecasting results. The proposed parameters are related to the reconciliation of variables that determine random events random non-negative events, which have a negative impact on the technological process technological process with variables that oppose the influence of random non-negative events and characterize the processes in object protection system. The importance of such consistency is determined by the need to ensure effective counteraction on the part of technological process to the possible influence of random non-negative events. New parameters are determined, which are a measure of the determinism of the transformations measure of determinism components of the forecasting system performed by individual components in the forecasting system and a measure of the influence of a system to counteract the negative impact of a random event on a technical facility component on the protection system TPr_i technological process, which activates the protection means TPr_i technological process by transmitting the relevant information to of the SZO object protection system included in the management system of the corresponding object $SUP_i(TPr_i)$ technological process control system.

The parameter of the degree of determinism measure of determinism components of the forecasting system of individual components or individual algorithms used in forecasting system is in a certain sense similar to the widely used parameter of prediction accuracy and, as a consequence, the accuracy of transformations implemented directly with the results of predictions. Due to the introduction of this parameter, it became necessary to use textual interpretations of the corresponding parameters, which made it possible to more closely associate this parameter with the subject area at the level of textual descriptions of the interpretation of the corresponding variables.

The use of the parameter measures of the impact of countering threats to the technological process, which determines the degree of influence of a system to counteract the negative impact of a random event on a technical facility on technological process control system, made it possible to expand the idea of ways to protect technological process control system and made it possible to determine the necessary degree of counteraction to the negative influence of random non- negative events. This accuracy value is determined by the degree of elimination of the influence of random non-negative events on technological process control system due to its compensation by the influence of a system to counteract the negative impact of a random event on a technical facility. This allows you to set the limits of the required accuracy of forecasting and transformations implemented in forecasting system.

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