Smart technologies of the risk-management and decision-making systems in a fuzzy data environment

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Article Info

Article history:

Received Jun 4, 2022
Revised Aug 31, 2022
Accepted Sep 12, 2022

Keywords:

Decision-making
Distribution density
Distribution law
Probability
Process
Simulation model

ABSTRACT

The purpose of this article is to provide a methodology for calculating and predicting the quality of solution implementation in complicated multi-parametric organizational and technological challenges with control agent uncertainty. The article's study findings are centered on the practical application of formal methods in predicting the outcomes of control and decision-making risks under the uncertainty of model agents. The proposed mathematics and simulation applications use a multi-agent strategy to handle the general problem of assessing quality control based on "producer risk (project customer)" and "user risk." Computer experiments with simultaneous graphical visualization of the results improve the accuracy of mathematical modeling, increasing the study's effectiveness. Under the uncertainty of system agents, a simulation model has been designed to analyze and anticipate the dependability of control and the hazards of decision-making. The suggested model is unique in that it takes into account the statistical nature of normative values as well as the rules of equal probability. To handle a frequent problem, the proposed system technique employs a dual approach. It accomplishes this by assessing the quality of the control process based on the magnitude of the risks in the decision-making system.

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1. INTRODUCTION

It is believed that SMART as a technology was proposed in 1954 by Peter Drucker. Then this technology was "packed" into the abbreviation S.M.A.R.T. Moreover, if this technology is focused on achieving personal goals, then each letter has the following interpretation: the goal should be S-specific; M-measurable; A-achievable; R-important, coincide with other tasks; T-with time frames. If a manager sets a task for other business entities, then the result and time resources, financial, material, personnel and laws are important for him. All this in a concrete and concise form is made out in the form of a business plan.

When managing large projects, SMART technology is considered as "setting goals", and was first published in 1965 by motivation specialist Paul J. Meyer. The difference of this approach lies in the specification of the goal, and then the author guarantees the “full” achievement of the result, which is incredible, i.e. possible risks are excluded. Detailing should be understood as the development of tasks. The goal is the end result, and the task is what needs to be done in order to achieve the goal [1]-[4]. Nowadays, this is all called systems methodology. Many questions, as well as answers to them, were stated in the works [5]-[8]. The works [5]-[7] show that the criterion of time in complex business projects may not be of primary importance, and only the formulation of the goal may take more than a year. The work [8] proposes a method of multicriteria analysis, which is based on a decision support system (DSS), and which combines two methods: the analytical hierarchy method (AHP) and the additive weighting method (SAW). This combination of two DSS methods is called hybrid DSS.

In works [9], [10], it was noted that in complex systems there can be only one goal and a standard definition of a goal is given, as something desirable and unattainable. Therefore, the goal cannot be quantified, and if it is achieved and measured, then this is a task. The abbreviation SMART is currently featured in many studies, publications and government programs, where it is interpreted as "smart" or "thinking" [11]-[15]. In some works, these technologies are given such names as: convergent technologies, NBIC (NBICS) technologies, information technologies, information and communication, digital technologies, etc.). In this variety, it is difficult even for a specialist to identify the specifics and technological differences in the attached list. A number of authors are looking for these differences at the philosophical level [16]-[20]. This approach is supported by interdisciplinarity and polydisciplinarity. “In Western literature, where the degree of development of the topic under consideration is much higher, they always strive to pay attention to the social, educational, philosophical components of the use of smart technologies” [21].

SMART technologies are often understood as digital technologies that cover: big data; neurotechnology and artificial intelligence; distributed ledger systems; quantum technologies; new production technologies; industrial internet; robotics and sensor components; wireless communication technologies; virtual and augmented reality technologies”. As noted in some articles, “Today it is impossible to find reasons why something cannot be made smart. The literature is written about smart clothes, smart food and smart nutrition, smart medicine, smart household appliances, smart management, smart behavior, smart education, smart leisure and even about a smart person. The main feature of smart technologies is “its subject-oriented approach”. The work [22] describes the possibility of using a system consisting of nine factors for the analysis of FES employees. The paper notes the insufficiency of this number of factors and proposes to supplement it with intellectual analysis.

Radical results from the introduction of a new generation of digital technologies in a number of countries, for example, in the UK, USA, Canada, Japan, and the Republic of Korea, gave rise to a new strategy, which was called "digital transformation", which is a multifactorial systemic socio-economic phenomenon [19]. From the many definitions of digital transformation, the following can be distinguished: World Bank Group, 2018a-"creating added value in the sphere of building digital resources and end-to-end digital processes"; UNCTAD, 2019-"directions of the radical impact of digital products and services on traditional sectors of the economy"; European Commission, 2019a-"changes in all sectors of the economy and society as a result of the introduction of digital technologies in all aspects of human life. Digital transformation is, as a rule, an innovative transformation of the product life cycle. The nutrient medium for digital transformation is: artificial intelligence (AI), robotics, unmanned vehicles, blockchain, virtual and augmented reality technologies, and a number of others.

Statistical studies of the demand for advanced digital technologies in the commonwealth of independent states (CIS) countries were carried out in the following sectors: agriculture, unmanned transport and logistics, fuel and energy complex, industry, construction, financial sector, healthcare. As a result of the research, it was revealed that the following digital technologies are in the greatest demand: big data, artificial intelligence; quantum technologies; new production technologies; robotics; distributed registry systems; wireless communication technologies; virtual and augmented reality. The use of big data is analyzed in [22]. As the author of the work notes, “big data represents one of the most profound and widespread evolutions in the digital world.” The internet of things (IoT) technologies, smart cars, and social networks. are given as examples. The rapid and not always controlled volumetric growth of data reduces its information quality due to the heterogeneity of information. Great prospects for smart technologies are opening up in the education system. Revolutionary changes in the use of digital technologies have occurred in education caused by the COVID-19 pandemic [23]. There has been a qualitative and quantitative leap in the use of online technologies in the control system of complex multi-parametric objects.

Currently, the following principles and approaches to building management models are most often considered in publications: i) from the standpoint of system dynamics in a multilevel environment of processes, considering feedback; ii) discrete-event modeling of procedures and operations in the environment of technological acts; and iii) agent-based modeling, which considers the system as a set of independent objects, each of which is functionally independent, and has both infrastructural connections and connections with the environment.

In practice, in complex systems it is impossible to adequately describe the functional set by only one modeling method, especially in the conditions of parametric fuzziness and fuzzy data. A complex system is considered to be stochastic with the presence of a human control in the circuit. The formalized definition of a multi-agent system is as follows [24]-[26]:

$$MAS = (A, E, R, ORG, ACT, COM, EV) \quad (1)$$

where *MAS* is a multi–agent system, *A* is a set of agents, *E* is a set of environments that are in certain relationships *R* and interact with each other, forming some *ORG* organization, having a set of individual and compatible actions *ACT* (strategy of behavior and actions), including possible *COM* communicative actions and the possibility of *EV* evolution. As a result, the following conclusion can be made: an agent is the development of the well–known concept of "object", representing some "augmented reality" in the objective world. The agent, as a system, contains software and hardware. Each author has the right to define his agent with a specific set of properties, depending on the development goals, tasks to be solved, implementation techniques, criteria.

Of all the management functions, control should be considered the key one, since "there is no control, there is no management" [27]. Control is a technology containing a set of objects and procedures, where each of them is independent of the others and can be considered as an agent of a complex system. Control plays a role not only as a tool for assessing the current state of the workflow, but also a predictive role, for example, in the supply chain and multi-objective optimization [28]. Control plays one of the crucial functions in software security management [29].

In this paper, it is proposed to ensure security not only at the stage of initial software development, but also to provide for internal control diagnostics during the workflow. In real conditions, control agents have a random nature, which in the process of control and decision-making leads to control errors that can be interpreted as risks, and risk management in order to increase the stability of the business system should be called robust control [30], [31]. Increasing robustness (stability, security), especially in e-business systems, seems to be effective using a hybrid algorithm, as proved in [32]. Control and robustness of control is of particular importance in such a modern technical area as the use of unmanned aerial vehicles. The use of unmanned aerial vehicles in the activities of various services opens up completely new perspectives. These devices can be used in the management and control of emergency situations, agriculture, and in the military field.

The analysis of common shortcomings in existing management systems, regardless of industry affiliation and form of ownership, can be reduced to the following problems: The problem with the normative framework. In science and practice, there are no objective methods for substantiating normative (limit, acceptable) values for controlled: parameters, indicators, factors and processes. Existing standards are periodically reviewed as statistical data accumulates or regulatory circumstances change dramatically in the external environment, etc. There are several methods of rationing used in practice, but subjectivity is more or less present in all existing practices. Therefore, at present, in many studies when modeling system processes, it is considered that the standards of magnitude are non-deterministic.

The second problem is that control, evaluation and decision-making are carried out in a differentiated way, i.e., separately according to individual parameters, for different tasks and under different conditions, since there is no integrated normative criterion, which at the scientific and practical level gives rise to the need to develop integrated indicator of management quality.

The third problem is the heterogeneity of data, which reduces the quality of the entire business process management system. The problem becomes extremely relevant when working with "big data". This real fact is noted in the literature and methods for estimating the homogeneity of statistical samples are proposed.

The fourth problem is defined by the ISO 2015 requirement. This standard contains a regulation to assess the quantitative value of decision-making risks in the form of "producer risk" and "consumer risk" [33]. To achieve this goal, a special supplement to the ISO 2015 standard has been developed under the name "risk management".

Scientific problem: the statistical nature of the structural system agents of the control process generates control risks, which are usually divided into "producer risk (design risk)" and "consumer risk". Quantitative assessment and forecasting of these risks is impossible without the involvement of mathematical apparatus and computer technologies. There are a number of works offering approaches to solving these problems. The problem of quantifying and predicting risks in the control and decision-making system is becoming extremely urgent in many fields of science and technology, for example, as noted above, in the use of UAVs and satellite imagery for the purposes of the Ministry of Emergency Situations. Under the existing circumstances of total digitalization of the economy and social sphere, along with the effective solution of some local management tasks, unforeseen problems appear, one of which is forecasting, quantification and risk management in multiparametric systems and fuzzy data conditions.

2. METHOD

Research methods: a systematic approach was used as a methodological basis in the studies. In the scope of theoretical research, scientific hypotheses were put forward, the purpose, criteria and objectives of the research were determined. As formalization tools, this article proposes a multi-method technique involving probability theory, mathematical statistics, simulation modeling, agent-based approach.

Research result: a graphical structural and functional model of a multi-agent control system, in this case, without the feedback of restoring normative functions, can be represented by Figure 1. The figure shows the quality management of the control process in a multiparametric system. As functional subprocesses, the following are investigated: measurement, comparison of the measured value with standards, analysis, decision-making.

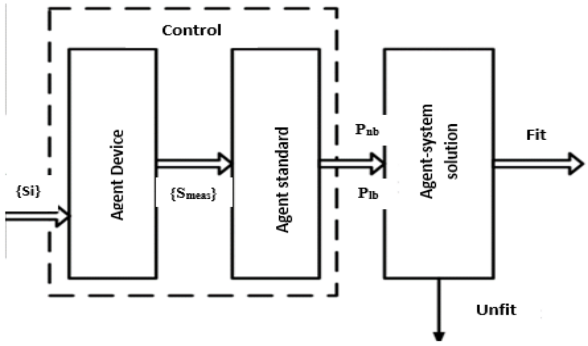

Figure 1. Multi-agent structural and functional control model

As follows from Figure 1, the control system is a multi-agent composition, in which, as a result of decomposition, the following agents can be distinguished: agent-flow of information S_i; agent-process of measurement S_{meas}; agent-process of comparison ($S_{meas} >< S_{н}$), analysis and formation of probable risks Rnb, R_{lb}; agent-process of decision (suitable or unfit).

In this context, "agents" combine such properties and concepts as: software and hardware technologically targeted entity; joint solution of some common problem by system aggregation; inter-agent exchange of information; modularity; extensibility and adaptability; multi-approach in the process of formalizing the functionality of agents; system openness. The agent "measurement" in this context can be considered in a fairly broad sense, regardless of its technological nature. Measuring instruments can be understood as: physical devices; measurement methodology; information revealed from the analysis of documents; a subject evaluating information with the help of available sensors. The result of the control is not a number, but one of the alternative statements: "the controlled characteristic (parameter) is within the permissible values", i.e. the result of the control is "fit"; "the controlled characteristic (parameter) is beyond the permissible values", the result of the control is "unfit".

The controlled parameters and technological control processes in real conditions have a non-deterministic nature, and are mathematically approximated by some distribution laws. However, in actual practice, the measurement accuracy is estimated only according to the metrological passport data of the tools by absolute and relative errors. A number of studies prove that the reliability of control and risks of control acquire a systemic character in the form of mathematical compositions of agent uncertainties [27], [31].

This approach is justified by the fact that "a parameter associated with the measurement result and characterizing the spread of values that can be attributed to the measured value with high probability". Uncertainties, as the authors suggest, are divided into three classes: uncertainties associated with the incompleteness of our knowledge about the problem on which a decision is being made; uncertainty associated with the inability to accurately account for the reaction of the environment to our actions, and, finally, an inaccurate understanding of their goals by the decision-maker. In the existing recommendations, uncertainty was understood as a statistical standard deviation. Currently, a standard has been developed-hazard analysis and critical control point (HACCP-hazard analysis, risk assessment and determination of critical control points), which was designed for quality control in the objective food control system. However, this standard is quite universal, and has become used in technical applications.

As noted, due to the fact that the measurement process technologically and at the formal level operates with uncertainties, control errors occur. Control errors are usually divided physically into errors called false and undetected defects. Quantitatively, these errors are estimated by the corresponding probabilities, in this case, P_{fd} - the probability of a false defect and P_{ud} - the probability of an undetected defect. In reliability theory, the term "failure" is used and the probable control errors are called spurious and undetected failures. These probabilities are also given a pragmatic meaning to risks, as the risk of the worker and the risk of the consumer of the work. Thus, the problem arises of developing formal models for assessing and predicting risks as a function of the statistical characteristics of the parameters of a multi-agent system. In a similar formulation, this problem was studied in the works cited earlier for the cases of deterministic norms. When measuring, the following probable events are possible:

- The true value of the Si parameter is within abilities $(S_l<S_i<S_u)$, and the measured value S_{imeas} exceeds the upper limit or goes beyond the lower limit $(S_{imeas}<S_l$ *or* $S_{imeas}>S_u)$. In this outcome, there is a case when the true value of the controlled parameter is in the acceptable zone - "fit", and the "unfit" erroneously fixes it outside the standard - "unfit". This case is called "false rejection" (undetected defect), and the probability of its occurrence - the probability of false rejection (undetected defect) P_{ud};
- The true value of the parameter S_i is outside $(S_i<S_l$ *or* $S_i>S_u)$, and the measured S_{imeas} value is within the allowable limits $(S_l<S_{imeas}<S_u)$. This case is called an undetected failure (undetected defect) and the probability of its occurrence is the probability of an undetected failure (undetected defect) P_{ud}.

In the above-mentioned works, this problem was solved under the condition of distribution of the distribution density function of the controlled parameter *f(S)* according to the Gauss or Weibull laws, and the measurement errors *φ(y)* according to the Gauss law, and the following analytical expressions were developed for quantitative assessment of control risks.

$$P_{fd}=\sum_{i=1}^{k}\left(e^{-\frac{s_i^{\beta}}{\alpha}}-e^{-\frac{s_{i+1}^{\beta}}{\alpha}}\right)\times\left[\frac{1}{\sigma_y\sqrt{2\pi}}\int_{S_н}^{S_i-3\sigma_y}e^{\frac{y^2}{2}}dy+\frac{1}{\sigma_y\sqrt{2\pi}}\int_{S_в}^{S_i+3\sigma_y}e^{-\frac{y^2}{2}}dy\right]$$

$$P_{ud}=\sum_{i=1}^{k}\left(e^{-\frac{s_i^{\beta}}{\alpha}}-e^{-\frac{s_{i+1}^{\beta}}{\alpha}}\right)\cdot\frac{1}{\sigma_y\sqrt{2\pi}}\int_{S_н}^{S_i-3\sigma_y}e^{-\frac{y^2}{2\sigma_y^2}}dy+\sum_{i=1}^{k}\left(e^{-\frac{s_i^{\beta}}{\alpha}}-e^{-\frac{s_{i+1}^{\beta}}{\alpha}}\right)\cdot\frac{1}{\sigma_y\sqrt{2\pi}}\int_{Sв}^{S_i+3\sigma_y}e^{-\frac{y^2}{2\sigma_y^2}}dy \quad (2)$$

The proposed work is intended for monitoring and operational quantitative assessment of the risks of controlling the parameters of an emergency event, for example, flooding of the territory or fire. Risk assessment occurs when studying events in the most dangerous areas of flooding or fire according to satellite information from the Ministry of Emergency Situations. The measured and controlled parameters of these events are dynamic and poorly predictable, so the use of normal statistical laws for these purposes is unacceptable. In this case, the case of maximum uncertainty is investigated, i.e., the equally probable distribution law of the controlled parameter. In the digital model of a satellite photo of a controlled area, the price of one pixel is 200 meters. The need for quantitative risk assessment is due to the extremely high cost of the satellite control system, and the low reliability of subjective management decisions made on the basis of this information.

In this article, the case of non-deterministic standards is considered, which corresponds to real practice. Recently, there have been works in which it is also proposed to consider standards as random values, such as in ecology. To develop mathematical models for estimating and predicting probable control errors with non-deterministic standards, some conditional controlled parameter *S* is selected. The distribution density function of this parameter is *f(S)*. The distribution density function of the random error of the measuring instrument is *φ(y)*. The following standards are designated: S_l–lower normative and S_u–upper normative and their statistical characteristics in the form of distribution laws.

$$\theta_1(S_l)=\frac{1}{\sqrt{2\pi}\sigma_l}e^{-\frac{\left(S_l-S_{l\,av}\right)^2}{2\sigma_l^2}};\ \theta_2(S_u)=\frac{1}{\sqrt{2\pi}\sigma_u}e^{-\frac{(S_u-S_{u\,av})^2}{2\sigma_u^2}}; \quad (3)$$

Where σ_l, σ_u – are standard deviations (uncertainties) of the lower and upper standard values; S_{lav}, S_{uav} - arithmetic mean values of the lower and upper standards.

In this case, the composition is considered, when the distribution laws of the norms S_u and S_l are approximated by normal laws, and the controlled parameter *S* is approximated by the law of equal probability. The law of uniform distribution (equal probability) is analytically given as a distribution density function and an integral distribution function as (4).

$$f(x) = \begin{cases} 0, x \notin [a,b) \\ \frac{1}{b-a}, x \in [a,b) \end{cases} \; and \;\; F(x) = \begin{cases} 0, a \leq x < a \\ \frac{x-a}{b-a}, a \leq x < a \\ 1, x \geq b \end{cases} \tag{4}$$

The average value of S_{lav} is the center of the area of uncertainty (scattering) of the lower standard. Similarly, the average value of S_{uav} is the center of the range of variations of the upper standard.

It follows from the formulated problem that the uncertainty parameters of the investigated agent model are: σ_s,-controlled parameter; mean square deviations σ_φ of random measurement error; σ_l, σ_u-standard deviations of standards.

The first step in modeling is to decompose the technological control process to the level of simple random event-procedures. As a result of the decomposition, the following events were revealed:

- Measurement of the current value of the controlled parameter S_i and obtaining the measured value of S_{imeas};
- Comparison of the measured value with the standard (standards) S_l, S_u;
- Decision-making.

In the future, the following designations are used:

- S-controlled parameter;
- S_i-the current value of the controlled parameter;
- $F(x_l)$, $F(x_u)$-integral distribution functions of the lower and upper standards;
- S_{imeas}-the current measured value of the controlled parameter;
- S_u-upper normative value of the controlled parameter;
- S_l-the lower normative value of the controlled parameter;
- $f(S)$-density function of the distribution of the controlled parameter;
- $\varphi(S_{meas})$-distribution density function of the random error of measurement of the controlled parameter S;
- a,b-uniform distribution parameters.

A simulation approach was chosen to model the risk formation process. A graphical model explaining the process of formation of control risks, with a uniform law of distribution of the controlled parameter, is shown in Figure 2.

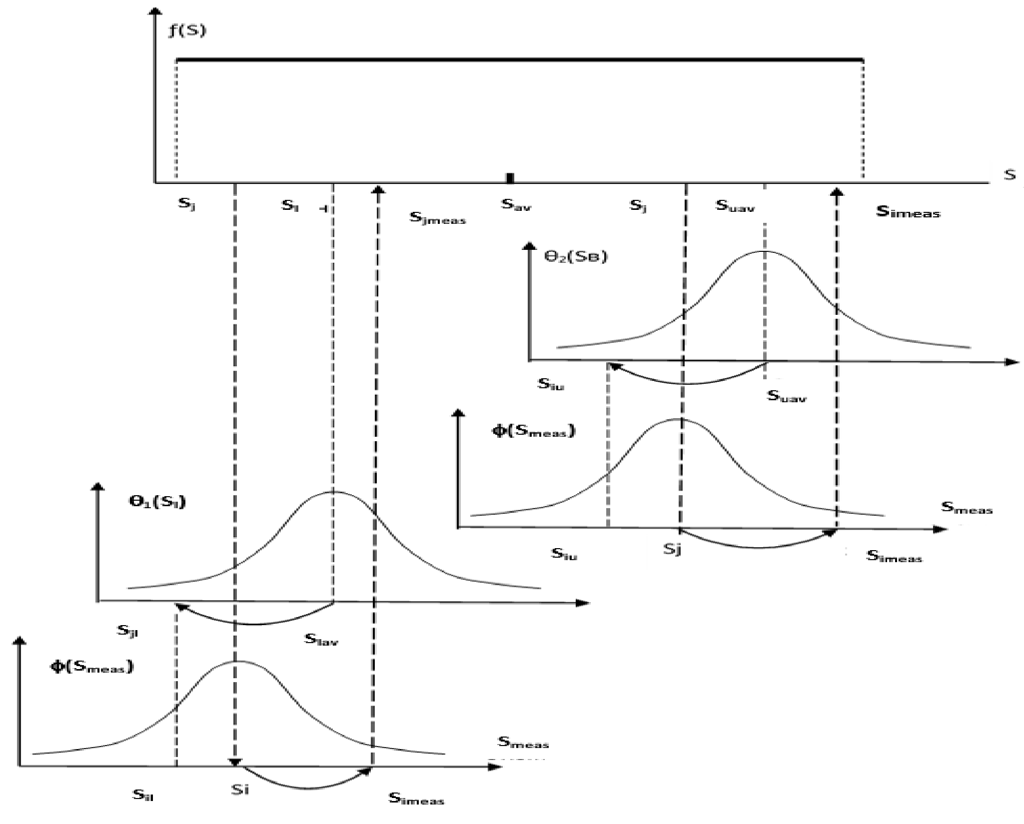

Figure 2. Graphical model of the simulation approach

When measuring by means that have a random error for the case of a tolerance limit of a controlled parameter, the following four possible events are possible:

- The true value of the Si parameter is within the allowable limits and the measured value is within the Simeas allowable limits;
- The true value of parameter Si is out of allowable limits and the measured value of Simeas is out of allowable limits;
- The true value of the parameter Si is within the allowable limits, and the measured value of Simeas is outside the allowable limits. In this outcome, there is a case when the true value of the controlled parameter is in the acceptable zone - “fit”, and the “device” erroneously fixes it outside the standard - “unfit”. This case is called a “false defect” (false refusal), and the probability of its occurrence is the probability of a false defect P_{fd};
- The true value of the parameter Si is outside the allowable limits, and the measured value is Smeas within the allowable limits. This case will be called an undetected defect, and the corresponding probability is an undetected defect P_{ud}.

The above group of events in probability theory is called the complete group of incompatible events. The first two cases of this group represent normal error-free outcomes and there is no need to take them into account in this task. A simulation model was developed for the quantitative calculation of the P_{fd} and P_{ud} probabilities, the algorithm of which is shown in Figure 3.

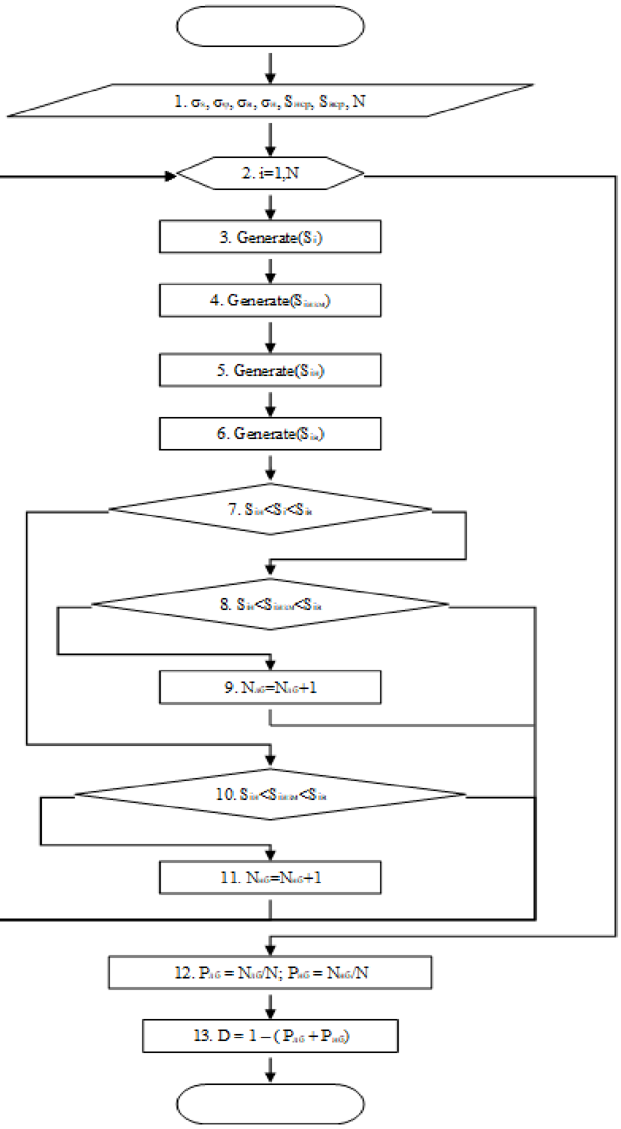

Figure 3. Simulation model for quantitative calculation of control errors under conditions of uncertainty of decision-making parameters

In block 1 of the model (Figure 3), statistical characteristics of the distributions are entered σ_s-the mean square deviation of the controlled parameter, σ_φ-the mean square deviation of the measurement error, σ_l and σ_u-the mean square deviation of the lower and upper standard values, S_{lav}, S_{uav}-the average values of the lower and upper standard values, *a*, *b*-the parameters of the equally probable of the law, *N* is the number of simulation's.

In block 2, a cycle from *1* to *N* opens. In blocks 3, 4, 5, 6 random values of the lower S_{il} and upper S_{iu} standards are generated ("played out"). Block 7 contains the logical condition IF (branching) $S_{il} < S_i > S_{iu}$. If $S_{il}<S_i>S_{iu}$, i.e. the S_i value is within the allowable limits (the condition is true-YES), then the condition for analyzing the measurement result $S_{il}<S_{imeas}>S_{iu}$ (block 8) now follows, and in the case of YES, the correct outcome, control is transferred to the organization of a new cycle to block 2. If in block 8 the condition if false – NO, then an error has occurred-a false defect, in block 9 the counter of these cases is triggered and a return occurs to the beginning of the next cycle block 2.

If the condition is false in block 7-NO, then the $S_{il}<S_{imeas}>S_{iu}$ condition is analyzed in block 10 and, if the correct outcome, control is transferred to the beginning of a new cycle (block 2), otherwise (NO) an error of undetected defect appears and the N_{nd} counter is triggered in block 11 and a new cycle begins in block 2.

Upon completion of a given number of simulations equal to *N*, in block 12, the probabilities of false and undetected defect are calculated according to the formulas (probable control errors)

$$Pfd = Nfd/N;\ Pnd = Nnd/N, \quad (4)$$

where:

N_{fd}-the content of the false defect counter;

N_{nd}-contents of the undetected defect counter;

N-the total number of simulated repetitions.

In block 13, the integral indicator of control reliability D is calculated using the formula $D = 1 - (Pfd + Pnd)$. Similar calculations can be made for different combinations of distribution laws and compare the degree of influence on the risks of control of the distribution laws of modeling agents.

3. RESULTS OF A COMPUTER EXPERIMENT

In the course of the computer experiment, the goal was to quantify the impact of uncertainties in the parameters of control agents on the risks and reliability of control. Quantitative assessment of control results was studied by simulation modeling of various variations of numerical combinations of statistical characteristics: controlled parameter, measurement error, standard values. Using simulation approaches to study problems of a metrological nature, it seems necessary to evaluate the methodological error of modeling, which largely depends on the number of tests (imitations). For this purpose, a computer experiment was carried out, the tasks of which included estimating the variance and computation time on a computer as a function of the number of imitations K. As an example, the number of hits of the observation results in the interval ±2σ was studied. Table 1 presents the results of the evaluation of the methodological error of computer simulation.

Table 1. Methodological error in the function of the number of tests

Number of imitations (K)	Error (δ %)
100	15.4
500	8.8
1,000	7.3
2,000	6.4

The test results showed that at K more than 2000 the error $\delta\,\%$ decreases extremely slowly. To conduct a computer experiment, a software application was developed, some screen copies of the program operation are shown in Figures 4 and 5. After entering all the necessary fields for calculating control errors and clicking the calculation start button, an element for displaying calculation results will appear.

To investigate the effect of changing of the characteristics' value of the measurement error or regulatory limits on the type and magnitude of the error, you must call the study form. This form is created by clicking on the corresponding button on the quick launch bar of the main window or calculation form, or can be called from the main menu of the application. One of the results of a computer experiment is shown in

3D graphical format in Figure 6. In Figure 6, the axes show: the reliability of the control D, the coefficient of variation, as the ratio of the measurement uncertainty to the uncertainty of the controlled parameter ($V\%=\sigma_{\varphi}/\sigma_s$), KRSR-the average allowable limits value in ss units. As follows from Figure 6, there is an area of minimum confidence, which is determined by calculation.

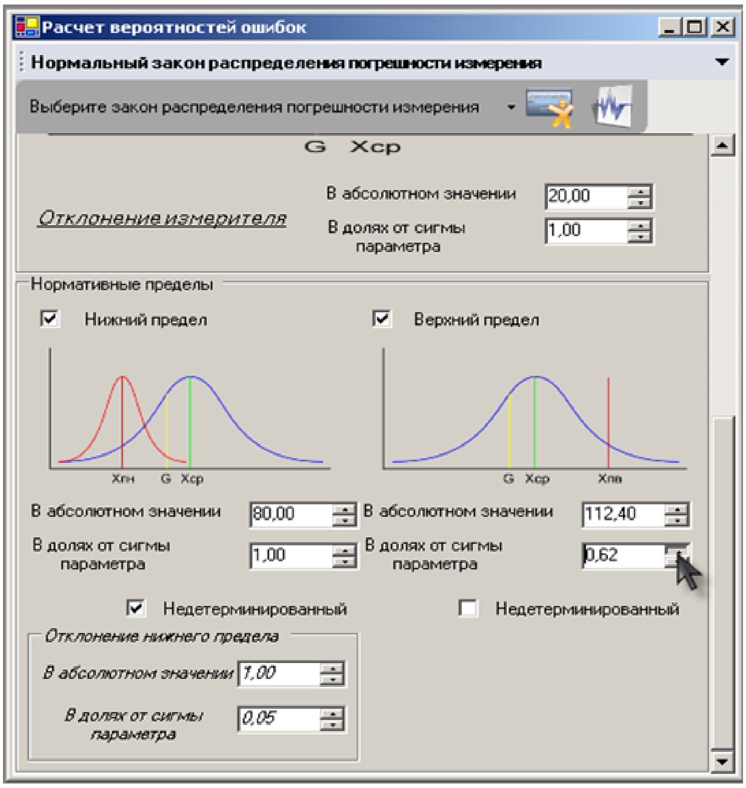

Figure 4. Entering the values of standard limits

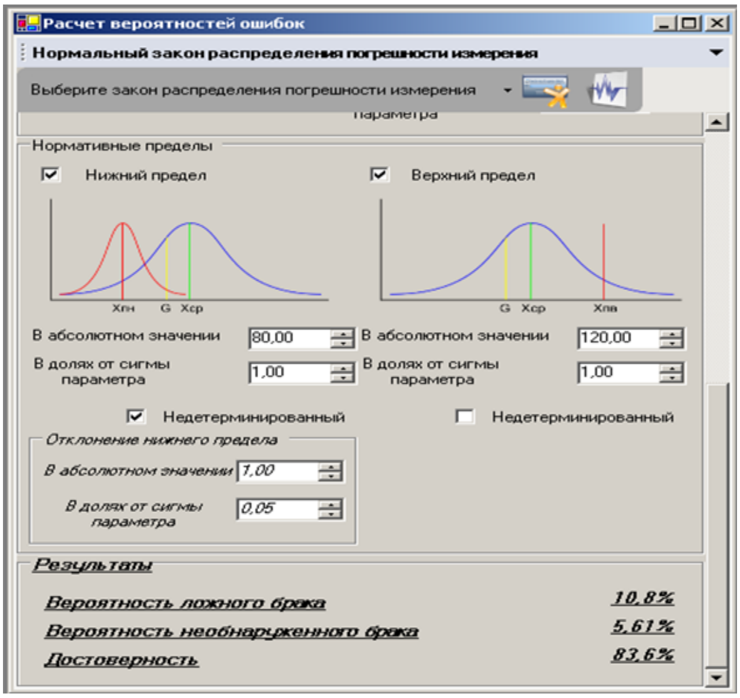

Figure 5. Results of the control errors calculation

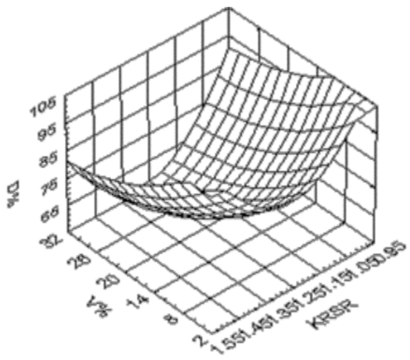

Figure 6. 3D modeling results

4. CONCLUSION

The results of the computer experiment showed that the statistical probability of control errors (risks) to a much greater extent depends not on the measurement error, but on the quantitative composition in the form of the ratio of mean square deviation (uncertainty) of the measuring instruments' error to the mean square deviation of the controlled parameter. The representation of simulation results in 3D spatial form allows you to visually assess the overall system picture of control results with all possible compositions of statistical characteristics of control agents.

During the computer experiment, it was also revealed that statistical combinations of control uncertainties have a greater effect on the probability of false marriage P_{fd} (the risk of the project customer). If the uncertainty of the measurement error σφ is commensurate with the value of σ_s, the risk may exceed 30%. At the same time, the influence of the uncertainty of the standards is higher than the influence of the error. From this follows the priority of the choice of standards for reasons of technical and economic rationality for each specific project. The results presented in the form of 3D show a picture of hidden parametric synergy, as can be seen from the figure, where the zone of minimum confidence is visualized, which poses a new task for developing a program for the analytical selection of this zone. The results obtained can be used as mathematical and methodological support for automated decision-making quality control systems in emergency management services.

ACKNOWLEDGEMENTS

The work was carried out within the framework of the grant funding project of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan IRN: AP08857126- "Development of a set of interactive training programs on the technological processes of repair of aviation equipment."

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