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Modeling, Control and Decision-Making Methods

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ABSTRACT: The analysis of the current state of the issues of modeling and controlling the technological processes of biotechnological systems with uncertain initial information was carried out, which showed that it is necessary to note the following: mathematical models of the main processes of biochemical production were obtained by the statistical method, however, analytical models were not sufficiently developed to take into account various regularities of the studied phenomena; the analyzed tasks contain all the fundamental difficulties that arise in the general control scheme with uncertain initial information and incomplete data. Therefore, to control the processes of biotechnological production, it remains relevant to develop such mathematical models that would take into account the technological features of the process.the integral level of their behavior. This approach makes it possible to describe the dynamics of the process and the kinetic behavior of the system with a very small number of parameters that need to be known in order to apply the models to real processes.

KEYWORDS: modeling, biotechnological systems, mathematical models, biochemical production, analyzed tasks, technological features, dynamics of the process, real processes.

Another approach to solving such problems is also very promising, when a mathematical description is obtained in the form of a statistical model. A wealth of modeling experience has already been accumulated in relation to chemical, metallurgical, food and other technological processes. The mathematical description of industrial facilities is used to select the optimal modes of operation of devices, the synthesis of control systems and the design of new technological processes. The mathematical description is a set of equations and limiting conditions that describe the static and dynamic relationships between the process variables of an object.

The study of the technological process according to its mathematical model includes several successive stages [1,14]. At the first stage, a choice is made or a new mathematical model is made on the basis of the idea of the process, in accordance with the objectives of the proposed study; on the second - the choice of a specific type of mathematical equations describing the process, the determination of the numerical values of the coefficients included in these equations; on the third stage, the simulation itself is carried out, i.e. obtaining the desired dependencies as a result of solving mathematical equations. Solutions are most often found with the help of computers by analytical, experimental-statistical or experimental-analytical methods.

The analytical approach is based on theoretical ideas about the nature of the process under study, the desired functional relationships are derived from a theoretical analysis of the physicochemical laws of the object under study, moreover, the mathematical description does not require setting up an experiment on the object; one can find the equations of statics and dynamics of the designed process; the derived equation for one object is applicable to describe an identical object; it is possible to improve control systems, study and improve technological processes [5, 11].

The application of this method makes it difficult to determine the coefficients of the mathematical description, the analysis and solution of equations, and in this regard, the method largely loses its validity when moving to the real conditions of an industrial facility.

For an operating industrial facility, characterized by limited information about the mechanism of ongoing processes, the experimental-statistical modeling method is more often used. It is based on the analysis of experimental data collected on a simulated object. For their processing, mathematical statistics and probability theory are used.

According to the method of accumulation of experimental data, active and passive methods can be distinguished [10].

To build a static mathematical description of technological processes, regression models with independent normally distributed errors and equally accurate measurements are often successfully used [6,7,8].

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Along with the positive experience of applying the method of regression and correlation analysis, there were cases when it was not possible to achieve the desired accuracy of the mathematical description due to incorrect consideration of the features of the technological process [11].

An experimental-analytical method has already been developed and is widely used, and the mathematical description is given on the basis of an analysis of the physicochemical features of the processes, and the numerical values are determined from data obtained directly from the simulated object. This method retains many of the positive properties of the two described. The complexity of some of the technological complexes under study is so great that the representation of all its elements in a single model is fundamentally impossible, therefore a hierarchical approach is important. For this, generalized models, characteristics of the lowest rank, and parametric distribution laws are used [11].

Management in complex multilevel systems is greatly complicated by the fact that in real production systems there are various types of uncertainty that may arise due to the fuzziness of measurements, goals, constraints and decisions. The decision-making process in multilevel hierarchical systems is also different in that the presence of clear (point) goals and decisions at each level of control and management and for each subsystem complicates the coordination process and predetermines the iterative nature of decision approvals.

When a researcher is faced with the uncertainty of a real system in the process of making decisions, he acts in a variety of ways: most often consciously (or unconsciously) ignores the existence of uncertainty and uses deterministic models; selects one of the most significant, from his point of view, type of uncertainty and uses the theory corresponding to this type, since the currently developed quantitative decision-making methods help to choose the best of many possible solutions only under conditions of a specific type of uncertainty; conducts additional studies of the system or obtains information in the course of control (adaptation and learning) [12] or management (dual control [13] of the system). The peculiarities of solving problems in real time lead to the fact that the lack of computational capabilities (the mismatch of computing resources with the complexity of the task) is equivalent in a sense to the lack of information about the conditions of the problem.

According to the work of M. Black [4], uncertainty occurs when the universal set consists of more than one point, i.e. if for these elements of the set, the corresponding probabilities or other probabilistic characteristics are given, then there is a probabilistic uncertainty. If only the boundary elements of the set are known, then there is complete uncertainty. And, finally, when setting for each element of the set the corresponding degree of membership - fuzziness.

Uncertainty can be classified by the degree of uncertainty (total uncertainty, probabilistic, linguistic, complete uncertainty), by the nature of uncertainty (parametric, structural, situational) and by the use of information obtained in the course of management (removable and irremovable) [11].

For a wide class of problems, a priori uncertainty can be reduced to parametric uncertainty, when the probabilistic distribution laws for the studied situations, quantities, and observed processes are known up to a finite number of parameters. In this case, the system can be controlled either on the basis of a priori information in the form of a program for the entire period of system operation, or using adaptive and recurrent estimation procedures to eliminate a priori parametric uncertainty using feedback control principles. In this case, the decision-making process is not reduced to a single act, but continues in the course of observation by a controlled object.

Depending on the degree of knowledge of the object, structural identification can be used (when the structure of the control object and the underlying physical laws are unknown) or parametric identification (if the uncertainty in the representation of the object can be reduced to the uncertainty of the vector parameter).

In the theory of control with incomplete information, an important place belongs to problems in which the unknown parameters of the control object are specified up to a priori estimates, and the control and identification processes must occur simultaneously. The latter circumstance led to the emergence of dual control theory [11], where, as a rule, unknown parameters are assigned probability distributions specified up to a priori estimates of random variables.

The presence of uncertainty in the decision-making process does not allow one to accurately assess the influence of control actions on the objective function. If the uncertainties that exist both in the system itself and in observations can be represented as stochastic processes, then stochastic control methods are applicable to such problems. However, there is a relatively large class of problems for which these methods are ineffective. The latter can be explained by the fact that the set of standard probabilistic concepts and methods is inadequate for describing the situations under consideration [13], as well as by the difficulty in obtaining the necessary statistical characteristics of the parameters, the lack of ergodicity of the processes and their significant non-stationarity. The source of uncertainty may not be of a random nature, and sometimes be partly or completely deterministic. The complexity of systems and the uncertainty of information about them is growing, and the requirements for the accuracy of the resulting solution are increasing. The

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requirements for the objectivity of the solution are also growing, and most often the criterion of objectivity is the use of classical deterministic models.

For individual objects, information on some parameters, goals and restrictions may be partially or completely absent. In this case, when only allowable ranges of parameters, goals, and restrictions are specified for objects, the presence of such minimal information leads to the need to use the apparatus of game theory. However, most often there is some additional information about the preference on the admissible area, and it is very difficult to take it into account in the framework of game theory. In this case, it is most convenient to use the apparatus of fuzzy set theory.

The presence in complex hierarchical systems of simultaneously different types of uncertainty makes it necessary to use solutions of the apparatus most common for all types of uncertainty - the theory of fuzzy sets [2, 13].

Accordingly, all information about the modes of operation of subsystems, the areas of admissibility and efficiency, objective functions, the preference of some modes of operation over others, the risk of operating in each of the modes for subsystems, etc. must be converted to a single form and presented as membership functions. This approach allows you to bring together all the available heterogeneous information: deterministic, statistical and linguistic.

Quantitative decision-making methods currently developed (such as expected utility maximization, minimax theory, maximum likelihood methods, cost-effectiveness analysis and others) help to choose the best of many possible solutions only under conditions of one particular type of uncertainty or under conditions of complete uncertainty. certainty. In addition, most of the existing methods for facilitating quantitative research in the framework of specific decision-making problems are based on extremely simplified models of reality and unnecessarily rigid restrictions, which reduces the value of the research results and often leads to incorrect decisions.

The use of the apparatus of probability theory for operating with uncertain values leads to the fact that the actual uncertainty, regardless of its nature, is identified with randomness, while the main source of uncertainty in many decision-making processes is fuzziness [3].

In contrast to randomness, which is associated with the uncertainty regarding the membership or non-membership of an object in a non-vague set, the concept of "fuzziness" refers to classes in which there can be various gradations of the degree of membership, intermediate between full membership and non-membership of objects in a given class. The issue of choosing an adequate language is very important, so the advantages of describing the decision-making process in a complex multi-level hierarchical system based on fuzzy set theory should be noted. This language makes it possible to more adequately reflect the essence of the decision-making process itself in fuzzy conditions for a multilevel system, to operate with fuzzy restrictions and goals, and also to set them using linguistic variables.[17,18]

Thus, the study of the features, principles of modeling, control and decision-making in biotechnological systems has shown that the technological processes of biochemical production belong to the class of multidimensional complex systems. Methods for modeling and managing such a class of objects remain insufficiently developed. These include biochemical production, which must take into account the topological structure and features of technological processes.

Since the technological system under study is complex and multidimensional, it is not yet possible to represent all its elements with the same degree of accuracy in a single model, moreover, the same degree of description is not needed. Therefore, the mathematical apparatus of the theory of fuzzy sets is accepted as the main apparatus for describing a multilevel hierarchical system, decision-making processes and control of technological processes in complex biotechnological systems. This approach makes it possible to develop scientifically substantiated systems for automatic control of similar classes of objects.

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