SYSTEM IDENTIFICATION for MANUFACTURING CONTROL APPLICATIONS

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The **SIMCA** Open Invited Track aims to bring together scientists working in all branches of control theory to discuss, in the light of **manufacturing control problems**, issues relating to development of the theory and methodology of identification, corresponding mathematical problems, parameter and non-parametric identification, structure identification and expert analysis, problems of selection and data analysis, control systems with an identifier, identification in intelligent systems, simulation procedures and software for identification and modeling, cognitive issues of identification, verification and problems of software quality for complex systems, global network resources of support processes of identification, modeling, and control.

Currently, there is no generally accepted definition of the concept of "identification of the manufacturing system". It is intuitively clear that this concept is extremely broad in scope, and the term "manufacturing system identification" can denote a large number of processes that are different in their properties and quantitative characteristics. Therefore, scientific studies of the problem of identification, which do not study certain types of identification and do not take into account the engineering context of their implementation, allow us to determine only the general characteristics of identification. With such a general approach, many problems of real or potentially possible identifications of manufacturing systems that are significant for engineering practice are outside the scope of scientific research.

However, over the past 50 years, it is the general approach that has acted as the dominant setting in scientific research in the field of identification. On the basis of a general approach, relying only on the results of mathematical research, heuristic ideas and general principles, almost all modern algorithms for identifying manufacturing systems have been designed.

The dynamics of the growth of scientific knowledge about the identification of manufacturing systems suggests that the possibilities of a general approach as a methodological basis for the creation of new identification algorithms are now almost completely exhausted. This hypothesis is also supported by the fact of the practical complete absence of detailed numerical studies of the characteristics and information capabilities of identification algorithms.

This state of scientific knowledge about identification is especially unacceptable at the present time, when there is every reason to believe that the Russian industry needs systemic modernization. The technical renewal of obsolete production assets is always associated with the commissioning of new, more efficient main technological equipment (control object) and, accordingly, with the commissioning of a new, more efficient management system. In this case, it is often necessary to put the control system into operation (or, at least, complete its installation) simultaneously with the commissioning of the main technological equipment, which in many cases is impossible without organizing the identification of the control object.

Difficulties in posing and solving the problem of identification are mainly due to the fact that the subject of identification is the team of ACS developers (automatic control system), and more importantly, the identity is a system object. Due to the systemic nature of identification, a systemic paradox arises in the identification process, a description of which was given back in the late 1960s. XX century in the work of A.V. Balakrishnan and V. Peterka. However, a scientifically based method of getting out of this paradox has not yet been developed, which undoubtedly indicates the difficulty of solving the problem of identification.

To increase the applied significance of scientific research on identification, an intellectual approach to the identification problem is proposed, based on four principles:

- on system-functional modeling of the intellectual activity of a team of developers in identification processes
- on the recognition of the decisive role of the human factor in the processes of identification;
- on consideration of identification as a system object and as a necessary component of a certain type of engineering practice for creating ACS ;
- on the definition of identification algorithms based on the formulation and solution of maximin problems of statistical synthesis of optimal identification algorithms.

The main goal of this work is to develop an intellectual approach to the problem of identification of manufacturing systems. This development is carried out in two directions: the content of the concept of "identification of manufacturing systems" is specified; the characteristics and information capabilities of four algorithms for identifying manufacturing systems are studied.

Apparently, various conceptual models of identification are possible and, in particular, models of the conditions for the emergence of identification within the framework of the engineering practice of creating ACS. In this work, it is considered that identification is implemented at the pre-project stages of creating an ACS before the development and approval of the terms of reference for creating an ACS. Secondly, it is believed that the decision to start identification is made only if the development team has:

- there is no reliable a priori information about an adequate mathematical model of manufacturing systems for the purpose of ACS design ;
- there is only a set of working hypotheses about the belonging of the indicated adequate model to the given families of mathematical models, parameterized by vector parameters with a given set of allowable values in the Euclidean or functional space.

Thirdly, it is considered that the given families of mathematical models are chosen in such a way that empirical estimates of vector parameters can be obtained using traditional methods of parametric and nonparametric identification.

A manufacturing system, in order to study the laws of functioning of which the team of developers is forced to organize identification, we will call a poorly studied control object. A poorly studied control object is considered to be a real object, in relation to which the development team does not have reliable a priori information about an adequate mathematical model for the purpose of ACS design , and there is only a set of working hypotheses about the belonging of an adequate mathematical model to given families of mathematical models.

Automation of a poorly studied control object always includes solving the problem of choosing the “best” hypothesis from a given set of working hypotheses about an adequate mathematical model of the control object. It seems that the stages of choosing the “best” working hypothesis and creating a new set of working hypotheses will continue until the degree of knowledge of the laws of the functioning of the manufacturing system reaches a level at which this object, from the point of view of the developers, ceases to be a poorly studied control object.

Based on the above ideas, the identification of a manufacturing system (briefly, identification) is an iterative process, each iteration of which includes the following main stages.

1) Finding a method for generating a set of working hypotheses about an adequate mathematical model of the manufacturing system for the purpose of ACS design.
2) Formation of a set of working hypotheses about an adequate mathematical model of the manufacturing system for the purpose of ACS design.
3) Finding a synthesis method for an algorithm for choosing the "best" hypothesis from a given set of working hypotheses.
4) Synthesis of an algorithm for choosing the "best" working hypothesis.
5) Determination of the "best" working hypothesis based on the developed selection algorithm and a given set of experimental data.
6) Finding a method for analyzing the "best" working hypothesis in terms of the requirements of the terms of reference for the creation of ACS.
7) Analysis of the "best" working hypothesis in terms of the requirements of the terms of reference for the creation of ACS.

The refinement of this definition is connected with the expansion of its content due to a detailed description of the final and intermediate goals of identification, its composition and structure within the framework of the conceptual model of a certain type of engineering practice of creating ACS. It seems that such a refinement can be obtained on the basis of the application of systematic and intellectual approaches. The idea of using a systematic approach as a methodological basis for setting and solving identification problems is not new to the scientific literature in the field of identification. Apparently, it was first expressed by V.Ya. Rotach . According to his ideas, the problem of experimental construction of a mathematical model of the control object for the purpose of designing the ACS (identification problem) and the problem of synthesizing the algorithm for the functioning of the controller based on the given mathematical model of the control object (optimization problem) cannot be solved autonomously, in isolation. Their formulations and solutions are causally related to each other, since they are interrelated system tasks in the process of creating an ACS that meets the requirements of the terms of reference.

The existence of a systemic paradox is derived from the systemic nature of the identification problem: “the task of constructing a mathematical model of an object is a *systemic task* that requires a *systematic approach for its solution* . This means that the choice of the criterion for approaching the object model to the real object must depend on the algorithm of the controller operation, for which the object model is built to find it. Thus, the task of building a model of an object turns out to be contradictory already in its formulation: to build a model of an object, you need to know the algorithm for the functioning of the controller, to determine which the model is needed (“paradox of the model” of the object, systemic paradox)).

The hypothesis of V.Ya. Rotach about the presence of a systemic paradox and his recommendation on how to get out of this paradox A.A. Krasovsky includes in the section "Modern requirements for applied control theory", which indicates the most significant, from his point of view, engineering methods of applied control theory.

The systemic nature of the identification task, according to V.Ya. Rotach, is also manifested in the presence of a system requirement, the fulfillment of which must be ensured by the mathematical model of the control object. This requirement is formulated as follows: “Let a control system for this object be built according to the object model, optimal in a given sense (ie, from the point of view of a given optimal control criterion). After the system is manufactured and installed on the object and put into operation, the control process will be characterized by some real value of the optimality criterion obtained as a result of synthesis according to the object model. It is obvious that the model should be considered satisfactory if the difference between the actual quality of the system and the expected calculated one turns out to be within the specified small limits.

To clarify the above, we note. The presence of a connection between the problem of identification and the problem of synthesis of the control system was indicated at the end of the 60s of the XX century. In the same work, apparently, the first description of the systemic paradox is given: “In fact, the identification of a technological process is only the first stage in solving a more complex control problem. In the process of this decision, the identification and synthesis of the control system must be considered together. This is easy to say, but much more difficult to implement. The fundamental difficulty lies in the fact that the mathematical description of the technological process must be adequate to the technological process for the conditions in which the control system being created will operate, but these conditions can be known only after the synthesis of the control system, for which, in fact, identification is required. Perhaps this is the main reason why the problem of identification is so often studied as an independent problem. However, the ultimate goal of identification must always be taken into account.”

Based on these ideas, the following definitions can be given. The ultimate goal of identification for the ACS design goal is to find an adequate mathematical model of the manufacturing system, i.e. a mathematical model, on the basis of which it is possible to carry out such a synthesis of the algorithm for the functioning of the regulator, that, based on the results of this synthesis, it is possible to design an ACS that meets the requirements of the technical task. The ultimate goal of identification is to find an adequate family of mathematical models of manufacturing systems, parameterized by a vector parameter with a given set of valid values in the Euclidean or functional space. An adequate family of mathematical models is a set of mathematical models, on the basis of which, in the process of parametric or non-parametric identification, it is possible to determine an adequate mathematical model of a manufacturing system.

The analysis of works on identification allows us to state that at present the methodological and mathematical foundations for creating the technical means necessary for the team of developers to achieve the ultimate goal of identification, understood in the sense of the above definition, have not been developed (with the necessary completeness and detail). This statement should not be interpreted as a statement that there are no methods and algorithms in scientific knowledge about identification that can be included in the mathematical software of support systems for the activities of developers of new technology in identification processes. Such methods and algorithms are available in sufficient quantity. The problem is not what to use (although this is important, given the wide variety of identification problems), but how developers should apply the available methods and algorithms in the implementation of their chosen conceptual identification model, and what result can they hope for?

Thus, manufacturing control problems relates to development of the theory and methodology of identification, corresponding mathematical problems, parameter and non-parametric identification, structure identification and expert analysis, problems of selection and data analysis, control systems with an identifier, identification in intelligent systems, simulation procedures and software for identification and modeling, cognitive issues of identification, verification and problems of software quality for complex systems, global network resources of support processes of identification, modeling, and control.