Digitalization as a tool for solving control problems

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Abstract. The article is devoted to the consideration of "digitalization" concept as a tool for solving control problems. The problems of digital twins formation are discussed and two directions for digital models creation are presented. The necessity of using a natural-model approach, methods of natural-mathematical modeling, similarity theory for building digital models is noted.

1 Introduction

Most publications in the media and in scientific literature widely advertise digitalization as a panacea for solving many scientific, technical and socio-economic problems. And only in a limited number of works it is noted that digitalization is only a tool, a means towards an end. An excessive enthusiasm for it can lead far away from strategic targets. This is especially clearly reflected in the work by V.I. Danilov-Danilyan "Ecology, hydrology, digitalization, digital twins and the elementary truths of modeling methodology" [1].

2 Systemic aspects of digitalization

In the article, the author examines some of the issues of digitalization which are associated with obtaining data on the functioning of already *existing* objects (systems) and building their mathematical models (analytical expressions, tables, graphs, etc., implemented, as a rule, in the form of computer programs), which now are called digital twins.

The author is right when he points out that:

1) obtaining data, no matter in what amount and in what form, is only a means for solving target problems;

2) the construction of mathematical models is a problem that the researches have been trying to solve for many decades, and yet has not found its solution. Digitalization has not brought anything new here.

The problems of data formation and construction of mathematical models should be considered not as separate directions, but as *integral parts* of general control problem [2]. This implies the requirements for the generated data in terms of accuracy, timeliness, etc.,

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as well as requirements for mathematical models, their adequacy, complexity, etc. [4]. Failure to comply with these requirements violates the "consistency" of the approach and can lead not only to ineffective, but also negative consequences.

3 Stages of digitalization

It should not be forgotten that the first wave of digitalization of the economy in the seventies and eighties of the last century, mainly at industrial enterprises, showed both positive results and problems of effective implementation and ways for their possible solution [5]. First of all, the freeing of almost all services at enterprises from the routine work of drawing up reporting documentation should be considered as positive results. The generated large volume of initial data provided by managers of various levels did not give the expected effect in the development of management decisions. Therefore, the question arose about the development of new forms of information presentation and, most importantly, the construction of automated control systems, and not simply information systems. This required the development of control algorithms that were effective in real conditions of enterprises operation and the training of qualified personnel capable of developing and operating control systems.

4 Approaches to building digital twins

Speaking about digital twins, it is necessary to distinguish two directions.

First.

Building a digital model of an existing object (system) for subsequent optimization. There are fundamental limitations here, which are indicated by

a) L. Leung [6] "The real system differs from the mathematical model we have built. We can say that *the world of mathematical descriptions is separated from the real world by an irresistible but transparent screen*. Looking at this screen-window, we can compare some features of physical systems and their corresponding mathematical models, but we can never guarantee their exact match";

b) V.Ya. Rotach [7] "A closer study of the control problem, however, shows the fundamental limitation of synthesis methods based on a priori given mathematical models of objects. The fact is that the synthesis of a control system based on a predetermined model of an object would be logically flawless if the properties of the model accurately reflect the properties of a real object. In reality, however, any model reflects these properties only with some degree of approximation. Accordingly, when constructing a model of an object, it is necessary first of all to select a criterion characterizing the error of such an approximation, and also to indicate the permissible value of this error. But to do this in isolation from the ultimate goal of building a model, that is, in isolation from the properties of the future regulation system, is fundamentally impossible. In other words, the choice of the approximation criterion when building a model of an object equally depends both on the properties of the object and on the properties of the future regulator, which will regulate the operating mode of this object, as well as on the choice of the indicator of control objective".

According to the principles of system analysis, the complete object of research should not be covered by feedback and forward control links. Failure to comply with this principle when generating data for identification will lead to inconsistent estimates of the model [2], no matter if data processing is be performed by known methods of mathematical statistics or by fashionable today neural networks. Then the special methods of data generation is required: the formation of planned experiments analogs, traditional methods of recording acceleration curves, applying test signals to the predicted trajectories of working control, applying test signals with the exclusion of the effects of control actions, applying physically labeled test actions.

One cannot agree with the author's statement that it is possible to build a model of technical objects, since many technological processes have the property of self-organization [8] and the technical objects, as a rule, are elements of the control system, and the man-operator controls subsystem. Therefore, it is necessary to consider a man-machine, and not a purely technical system.

But even an adequate mathematical model is not enough, since the rules for transferring the results of mathematical modeling to a twin object being the full-scale object are necessary. And here we need a theory of similarity. And if the similarity theory is developed well enough for control objects, then for control systems it is currently only in its infancy [9, p. 56-58].

Second.

Building a digital model of a non-existent object (analytical models) for the purpose of creating fundamentally new technologies, control systems, etc. In this case, rules are also needed for the transition of a digital twin to a full-scale one. This issues of this kind in similarity theory are not even mentioned.

5 Digitalization and prediction of states and outputs of control objects

It is most important to take into account the following features when predicting in control systems [10]:

1. Prediction should be conditional, namely, under the condition of the trajectories of control actions actually realized up to the current moment of time and fixed after this moment in time.

2. The results of prediction can affect significantly through the implementation of control actions on the properties of the prediction object, which, in turn, entails a deterioration in the prediction effectiveness itself. This systemic paradox is, in fact, similar to what is observed when objects are identified in control systems.

3. Since in control systems sometimes up to 50% of variations in output indicators are caused by uncontrolled disturbances, it is necessary to estimate and extrapolate the reduced disturbance, which represents the cumulative effect of all such disturbances.

The use of the obtained digital initial data and their digital processing does not change the structure of the predicting system

6 Conclusion

As long-term experience shows [11], when creating new technologies, units, systems, it is more justified to focus on the natural-model approach, rationally integrating mathematical and physical models, as well as full-scale elements of control systems.

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