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Formalization of the problem and principles of constructing mathematical models MSP control systems

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ABSTRACT: Formalization of the problem and construction of mathematical models of control systems are important stages in the research and design of complex systems. The article discusses the features of mathematical modeling of MSP. The use of the latest mathematical modeling tools and modern computer technology mainly determines the prospects of such research [11].

I. INTRODUCTION

One of the biggest bottlenecks in the creation of MSP control systems, which allow intensifying processes and increasing production efficiency, is the issue of modeling. At the same time, the structure and accuracy of the mathematical model largely determines the effectiveness of the entire MSP management system.

Models often act as integrating elements of the control system, combining and processing information coming from various subsystems of the control system in order to obtain analytical and predictive data on the functioning of the control object. The quality of such models - their adequacy, completeness, efficiency - largely determines the level and quality of management of objects as a whole.

Multi-stage processes are complex modeling systems, the analysis of the dynamics of functioning and the synthesis of optimal solutions of which is possible in real situations only on the basis of the use of a PC. Therefore, modeling methods are subject to a range of requirements associated with the machine orientation of models, with the possibility of their use in the problems of complex analysis of the functioning of a multi-stage system and the synthesis of a flexible control system. In broad terms, this part of the requirement is as follows: modularity, hierarchy, formalizability, machine orientation and universality.

This circumstance is due to the peculiarities inherent in the mathematical modeling of MSPs.
The first group of features of modeling discrete-continuous MSPs is associated with the special quality of these systems - flexibility, the second - with the high complexity of the modeling process, due to, as well as the inclusion in the simulation of a large number of heterogeneous features of elements, the coordination of which is a prerequisite for organizing the interaction of elements. The third group of features is associated with the high responsibility and laboriousness of the MSP modeling process.

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II. MATERIAL AND METHODS

The complexity of discrete MSPs as modeling objects is due to a number of objective factors, including the heterogeneity of the medium, the heterogeneity of the material according to various characteristics (size, shape, mineral composition of particles), the complexity of the interaction of various physical and chemical factors in the production process. As a result, each technological operation has an equal degree of influence on the final results of TP, therefore, in the MSP control system, separate control loops are distinguished - technological sections with a certain number of input and output material and information flows. The selected contours can be considered independently of the rest of the MSP, and it is necessary to develop control and identification algorithms for them. For each contour, its mathematical model is built, goals, control tasks and technological organic ones are formulated that are imposed on the control process.

III. RESULTS ANS DISCUSSION

The task of constructing a mathematical model of a continuously functioning process is formulated as follows.

Parameter $\mathcal{X}(t)$with components $\mathcal{X}_1(t), \mathcal{X}_2(t), \dots, \mathcal{X}_s(t)$act on the input of the circuit and $r -$ the output parameter is given $\mathcal{Y}(t) = \mathcal{Y}_1(t), \dots\dots, \mathcal{Y}_r(t)$ [5,8], and each of the output parameters $\mathcal{Y}_1(t), \mathcal{Y}_2(t), \dots\dots, \mathcal{Y}_r(t)$ is completely determined in the probabilistic sense by all or part of the input $\mathcal{X}_1(t), \mathcal{X}_2(t), \dots, \mathcal{X}_s(t)$. At the same time, it is fundamentally impossible to take into account all the input parameters that affect the course of the process, and output variables; in practice, one has to limit oneself to only a small part of the main determining input parameters, the rest are attributed to uncontrolled disturbances (noise). The task of the control system is to compensate for these disturbances. In addition, certain restrictions are imposed on the input and output parameters. *G (x), G (y).*

In the general case, the system of equations describing the process under study is expressed as follows:

$$\mathcal{Y}_j = f_j(x_1, x_2, \dots\dots, x_r, \mathcal{Y}_1, \mathcal{Y}_2, \dots, \mathcal{Y}_{j-1}, \mathcal{Y}_{j+1}, \dots, \mathcal{Y}_S, a_0, a_1, \dots\dots, a_m)$$

Or

$$\mathcal{Y} = a_0 + \sum_{i=1}^{\mathcal{K}} a_i x_i + \sum_{\ell,\ \substack{i=1 \\ l \neq i}}^{\mathcal{K}} a_{\ell i} x_\ell x_i + \sum_{i=1}^{\mathcal{K}} a_{ii} x_i^2 + \dots..$$

The function $f_j(j = \overline{1, \mathcal{S}})$ can be fairly well approximated by functions $\hat{f}_j(j = \overline{1, \mathcal{S}`}, \mathcal{S}` < \mathcal{S})$given up to a set of parameters $b = (b_0, b_1, \dots, b_m)$, i.e.

$$\mathcal{Y}_j \approx \mathcal{Y}_j^* = \hat{f}_j\left(x_1, x_2, \dots\dots, x_r, \mathcal{Y}_1, \mathcal{Y}_2, \dots, \mathcal{Y}_{j-1}, \mathcal{Y}_{j+1}, \dots, \mathcal{Y}_S, b_0, b_1, \dots\dots, b_m\right) \ (1)$$

or

$$\mathcal{Y}_j \approx \mathcal{Y}_j^* = b_0 + \sum_{i=1}^{\mathcal{K}} b_i x_i + \sum_{\ell,\ \substack{i=1 \\ l \neq i}}^{\mathcal{K}} b_{\ell i} x_\ell x_i + \sum_{i=1}^{\mathcal{K}} b_{ii} x_i^2 + \dots.. \qquad (2)$$

Where $j = \overline{1, \mathcal{S}`}$ и $b = (b_0, b_1, \dots, b_m)$ – uncertain coefficients of the mathematical model.

Based on experimentally obtained values$\mathcal{Y}_j \in G(y)$. And $\mathcal{X}_{iб} \in G(x), (j = \overline{1, \mathcal{S}`};\ б = \overline{1, \mathcal{S}`}, i = \overline{1, n})$ parameters (1), (2) can be estimated using the least squares method [1,11,13].

A block diagram for constructing a mathematical model for one subsystem of the MSP is shown in fig. 2

When modeling multidimensional systems, one has to operate with various factors that have different units of measurement. Therefore, it is advisable to define a dimensionless mathematical model, since it is easily analyzed. You can also derive recurrence relations that allow you to move from a dimensionless model to a dimensional one.

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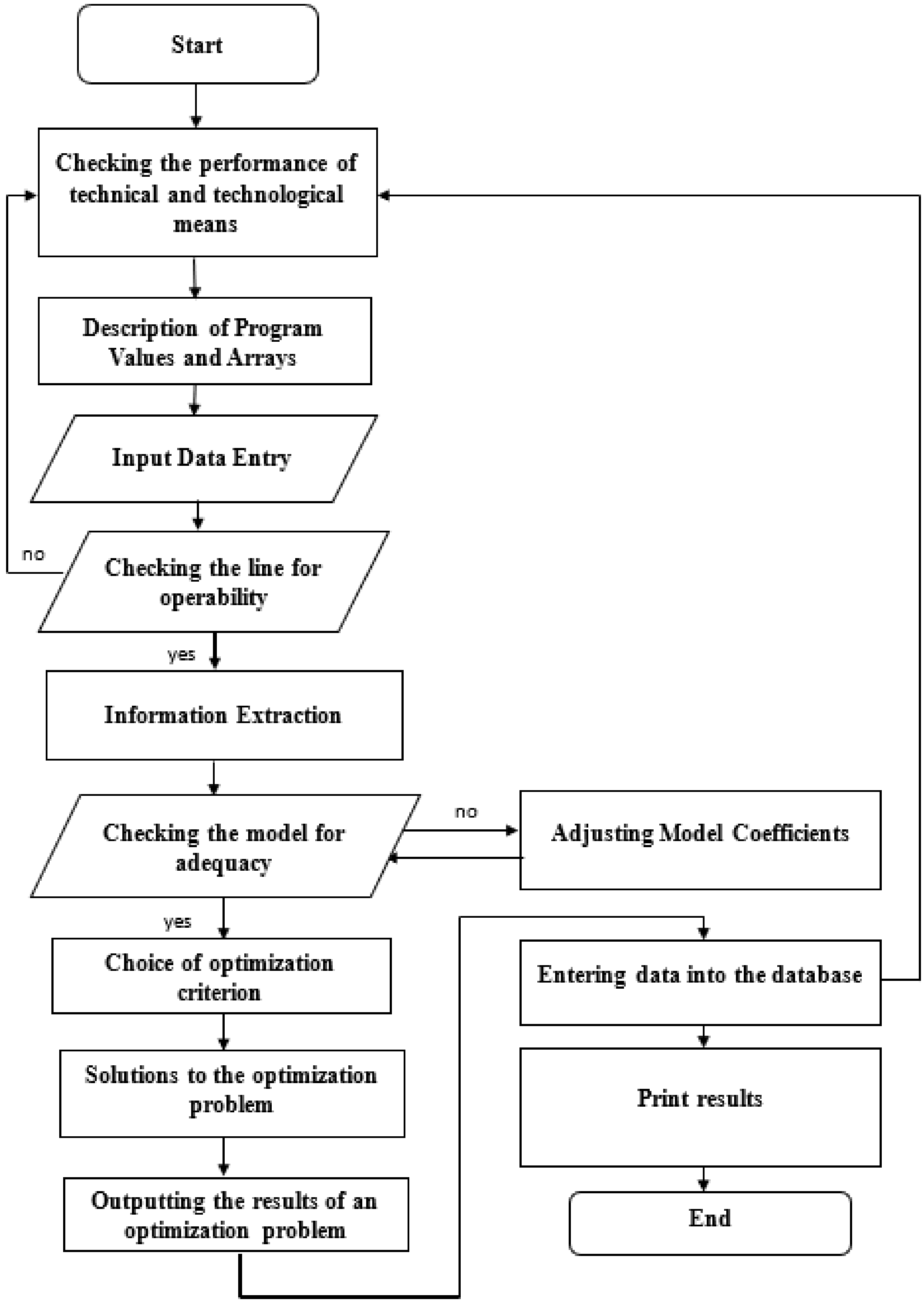

Fig.2. Algorithm for solving the problem.

For this purpose, instead of the components of the initial factors, standardized (dimensionless) ones are introduced:

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$$\mathcal{C}_{x_{is}} = \frac{x_{is} - \mathcal{M}_{si}}{б_{xi}}, \mathcal{C}_{y_s} = \frac{y_s - \mathcal{M}_y}{б_y}, \qquad s = \overline{1,m}, i = \overline{1,n},$$

Where,

$$б_{x_i} = \sqrt{\frac{\sum_{s=1}^{m}(x_{is} - \mathcal{M}_{xi})^2}{m-1}}, б_y = \sqrt{\frac{\sum_{s=1}^{m}(y_s - \mathcal{M}_y)^2}{m-1}},$$

$$\mathcal{M}_{x_i} = \frac{1}{m}\sum_{s=1}^{m} x_{is}, \mathcal{M}_y = \frac{1}{m}\sum_{s=1}^{m} y_s,$$

Here the approximate regression equation has the form

$$\mathcal{C}_y = \alpha_1 \mathcal{C}_{x_1} + \alpha_2 \mathcal{C}_{x_2} + \dots + \alpha_n \mathcal{C}_{x_n} \qquad (3)$$

After not complex transformations, we obtain a system of equations for unknown coefficients α_1, which in matrix form looks like this [11,12,13]:

$$\mathcal{D}_\alpha = \beta,$$

Where

$$\mathcal{D} = \begin{pmatrix} d_{11} & d_{12} & \dots\dots & d_{1n} \\ \dots & & & \\ d_{n1} & d_{n2} & \dots\dots & d_{nn} \end{pmatrix}, \alpha = \begin{pmatrix} \alpha_1 \\ \vdots \\ \alpha_n \end{pmatrix}, \beta = \begin{pmatrix} \beta_1 \\ \vdots \\ \beta_n \end{pmatrix}$$

Or

$$\mathcal{D} = d(i,j), \qquad \alpha = \alpha(i), \qquad \beta = \beta(j),$$

$$d_{ij} = \frac{1}{m}\sum_{s=1}^{m} \mathcal{C}_{xis}\, \mathcal{C}_{xjs}, \ (4)$$
$$\beta_j = \frac{1}{m}\sum_{s=1}^{m} \mathcal{C}_{ys}\, \mathcal{C}_{xjs}, \ i,j = \overline{1,n}.$$

If for a quadratic matrix $\mathcal{D}$there is an inverse matrix $\mathcal{D}^{-1}$, then multiplying (4) on the left by $\mathcal{D}^{-1}$, we find the unknown coefficients of the system d_i[14,15]:

$$\alpha = \mathcal{D}^{-1}\beta$$

Substituting the coefficients into the approximate regression equation (3), we find a dimensionless mathematical model (on a standardized scale) for describing the multidimensional system under study.

IV. CONCLUSION

Thus, at present, mathematical modeling methods are the most convenient, reliable and relatively cheap methods for studying real MSPs.
The use of the latest mathematical modeling tools and modern computer technology mainly determines the prospects of such studies.

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REFERENCES

[1]. Bern Klein, M. Bruce Redden, and Thomas M. Fulton. "Flotation Process Optimization Through Frequent In-Line Grade Measurement as an Instrument for Automatic Control"
[2]. Jan Cilliers "Optimization of Flotation Circuit Configurations" .
[3]. Daniel Sbárbaro "Advanced Control and Supervision of Mineral Processing Plants".
[4]. R.P. King. "Modeling and Simulation of Mineral Processing Systems".
[5]. V.E. Ross ."Flotation Optimization: Testing Variables".
[6]. Christopher J. Greet, Bradshaw D.J., R. J. Tomas. "Flotation Plant Optimisation: A Metallurgical Guide to Identifying and Solving Problems in Flotation Plants".
[7]. Smith, G.C., Jordaan, L., Singh, A., Vandayar, V., Smith, V.C., Muller, B. and Hulbert, D.G. Innovative process control technology for milling and flotation circuit operations. The South African Institute of Mining and Metallurgy, 2004.
[8]. Thermo scientific multi-stream analyzer (MSA) XRF Elemental Slurry Analyzer Product Specification Sheet (2008).
[9]. OUTOTEC COURIER® 5i SL and Courier® 6i SL Product Specification Sheet (2008).
[10]. Haavisto, O. Reflectance Spectrum Analysis of Mineral Flotation Froths and Slurries. Dissertation for the degree of Doctor of Science in Technology. Faculty of Electronics, Communications and Automation, Helsinki University of Technolgy, Finland (2009).
[11]. Makhamatov N.E., Yakubov M.S., Sharifzhanova N.M. Simulation of a multi-stage process of ore beneficiation flotation. – T.: «Fan va texnologiyalar nashriyot-matbaa uyi», 2023. 136 p.
[12]. N.M. Sharifzhanova, M.S. Yakubov, Francesco Gregoretti. Adaptation algorithm for self-tuning of parameters of multi-stage flotation process models (2024).
[13]. N.M. Sharifzhanova, M.S. Yakubov. Current status of management of multi-stage flotation processes
[14]. N.M. Sharifzhanova. Principles of complex multi-stage processes decomposition into component subsystems. E3S Web of Conferences 474, 01052 (2024) ICITE 2023, https://doi.org/10.1051/e3sconf/202447401052
[15]. N.M. Sharifzhanova, F. Gregoretti. Adaptation algorithm for adjusting the parameters of the flotation process