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SCIENTIFIC PRACTICE: MODERN AND CLASSICAL RESEARCH METHODS

FEBRUARY 26, 2021 • BOSTON, USA

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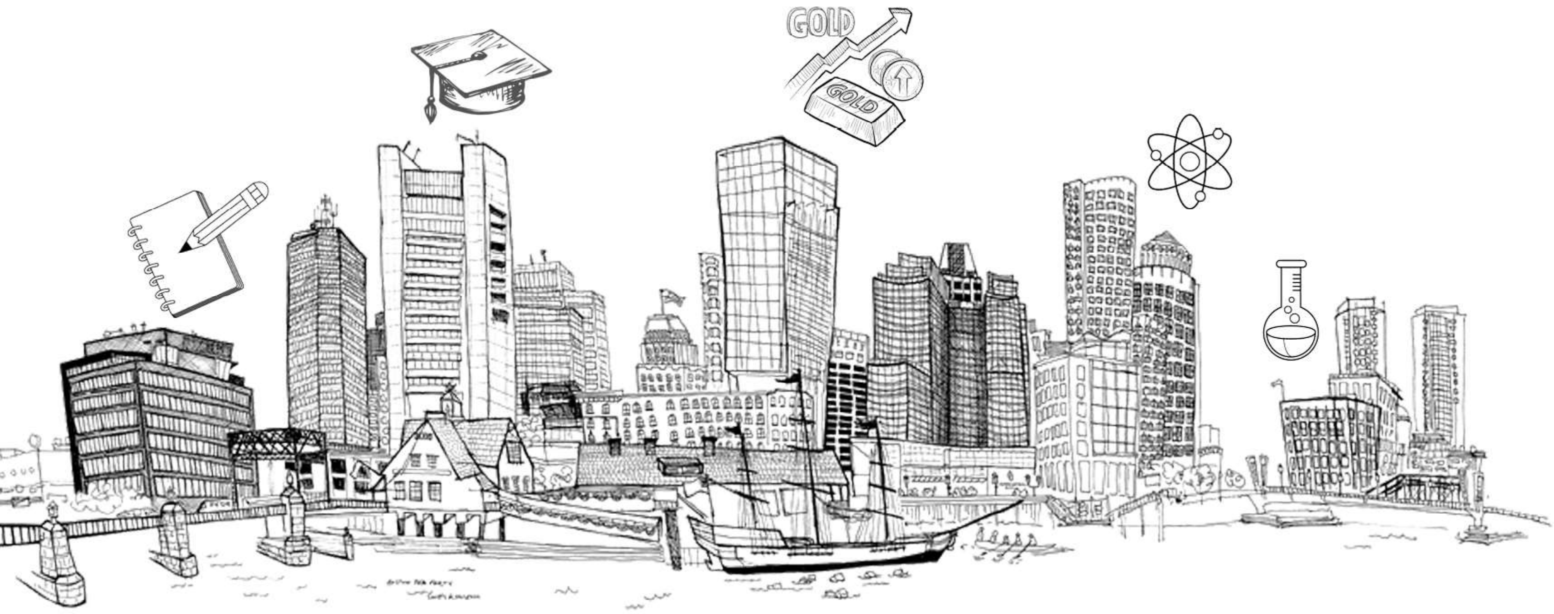

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CONTENT

SECTION XX. INFORMATION TECHNOLOGIES AND SYSTEMS

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ANALYSIS OF THE IDENTIFICATION PROBLEM OF DYNAMIC SYSTEMS UNDER UNCERTAINTY

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Management is understood as an organizational activity that carries out the functions of managing any work aimed at achieving certain purposes [1]. The management process consists of analyzing the decision-making process on the most appropriate actions in relevant situations. The person who manages, decides, assessing the environment with the help of information received from their senses, measuring instruments, other persons and technical devices. In many cases, this information is insufficient for an unambiguous assessment of the situation. Then experience, knowledge, memory, intuition are used. A remarkable human property is the ability to make decisions in conditions of significant uncertainty about the environment with the receipt of appropriate information.

There have been developed mathematical methods that allow analyzing existing types of information, filtering out unnecessary information and highlighting its most essential part in order to manage. Also, one should use the necessary information to assess the current situation and develop recommendations that ensure the most effective implementation of the management objectives of the situation. Model selection in solving management problems and the study of continuous processes is due to both the implementation of the conditions and requirements of adequacy. In conditions of uncertainty in the fore algorithms and methods information analysis data of different structure, wherein the analysis information is a part of the identification system.

To solve the problem of control in conditions of uncertainty, the methods of the theory of adaptive systems are used, which allow [2]: to ensure high accuracy of control with a significant change in the dynamic properties of the object; to optimize the operating modes of the object in conditions of changing its characteristics; improve system reliability; unify individual control subsystems and their blocks; reduce the development and delivery time of the system. Adaptive methods are used to solve problems in which there is no information about the nature and conditions of the object's functioning, as well as in the case of impossibility or insufficiently complete formalization of a priori data.

In the general case, the process of synthesis of an adaptive system can be divided into several stages [2]. First, the purpose of control is formed and requirements are set for the structure of the mathematical model of the object. For this, a priori and/or experimental information is used. In a more general case, the synthesis of a system is associated with solving the problem of structural identification. At the second stage, the structure of the control device is determined. Next, the algorithm for adapting the controller parameters is selected. At the final stage, the adopted algorithm is justified. Object identification is reduced to determining the structure and parameters of the model based on the observed data (input and output of the object) and available a priori information. All existing approaches to identification are divided into two groups – statistical and multiple-functional (deterministic). The indicated classes differ by taking into account the nature of disturbances (noises) acting on the system and by the estimates obtained. For the statistical approach, requirements were put forward for the structure of the object model, and with respect to all uncertain factors and interferences, it was assumed that they were random [1]. Despite a wide variety of algorithms and identification methods, there are no procedures for regular synthesis of the structure of the model, which is explained by the complexity and variety of control objects, poor knowledge of the processes occurring in the object.

A plurality of dynamic processes in the management objects can be described by a differential equation with a single input *u* and the output *y*

$$a_0 y^{(m)} + a_1 y^{(m-1)} + \ldots + a_m y = b_0 u^{(k)} + b_1 u^{(k-1)} + \ldots + b_k u + \xi, \qquad (1)$$

where: ξ – random outrage; a, b – weight coefficients of the differential equation.

From equation *(1)*, you can go to the finite-difference representation. Considering $t = n\,\Delta\,t$, where $n = 0, 1, \ldots$, Δt – data reading interval, and by entering the *z* operator offset back $zy(n) = y(n-1)$, get

$$D_y(z) y(n) = D_u(z) u(n) + \xi(n), \qquad (2)$$

where: $D_y(z) = a_0 z^m + a_1 z^{m-1} + \ldots + a_m$, $D_u(z) = b_0 z^k + b_1 z^{k-1} + \ldots + b_k$.

If $\xi(t)$ is a random sequence, then *(2)* is an autoregression equation - a moving average, and when $D_u(z) = 1$ – a moving average model. In the general case, the autoregression equation - a moving average with dynamic specification for $\xi(t)$ in the space {*U*, *Y*} has the form

$$Y(t) = F(A, Y(\tau_1), U(\tau_2), \xi(\tau_3), \tau_i \in [t_{\tau_i}, t], i = \overline{1,3}), \qquad (3)$$

where: $t_{\tau_i} \geq t_0$.

It can be seen from *(3)* that the dynamic properties of an object can be determined both by its internal structure and by the dynamic properties of the input $U(t)$ and interference $\xi(t)$.

Equations *(1)-(2)* can be written in matrix form (in the form of a state space). For a linear stationary plant, the equations in the state space have the form

$$\begin{aligned} \dot{\mathbf{X}} &= \mathbf{AX} + \mathbf{BU} + \xi, \\ \mathbf{Y} &= \mathbf{CX} + \mathbf{DU} + \zeta, \end{aligned} \qquad (4)$$

where: $\mathbf{X} \in \mathbf{R}^m$ *– state vector;* $\mathbf{A} \in \mathbf{R}^{m \times m}$ *– state matrix;* $\mathbf{U} \in \mathbf{R}^{n \times k}$ *– input vector;* $\mathbf{Y} \in \mathbf{R}^n$ *– output vector;* $\mathbf{B} \in \mathbf{R}^{m \times k}$, $\mathbf{C} \in \mathbf{R}^{n \times m}$, $\mathbf{D} \in \mathbf{R}^{n \times k}$; $\zeta \in \mathbf{R}^n$ *– unobservable vector of measurement errors;* $\xi \in \mathbf{R}^m$ *– obstacle vector.*

The first equation in *(4)* is called the equation of state, and the second is called the measurement (observation) equation. In identification problems, matrix **D** is usually equal to zero.

Any object can be characterized by a set of variables $\vec{\mathbf{u}}(t) \in U$ arriving at its input and a set of variables $\vec{\mathbf{x}}(t) \in X$ that are the object's response to the impact and reflect its state. The object is immersed in the external environment, the influence of which is manifested in the form of controlled $\zeta(t) \in \Xi$ and uncontrolled $\xi(t) \in \Sigma$ disturbances and also affects its state. In identification problems, controlled disturbances are included in the input vector $\vec{\mathbf{u}}(t)$. Uncontrolled disturbances $\xi(t)$ manifest themselves through the output of an object $\vec{\mathbf{y}}(t) \in Y$ belonging to X and is only a part of the state vector, that is, $Y \subseteq X$. The information space of the object is represented as [1, 2]

$$\mathbf{I} = \mathbf{U} \times \mathbf{X} \times \mathbf{\Psi} \times \mathbf{J} \times \mathbf{S},$$

where: $\mathbf{\Psi} = \mathbf{\Sigma} \times \mathbf{\Xi}$ *– perturbation space;* **J** *– object observation interval;* **S** *– system parameter space*

$$\mathbf{S} \subseteq \mathbf{R}^m \times \mathbf{R}^n,$$

$\mathbf{K} \subseteq \mathbf{R}^n$ *– space of structural features of the "object + environment" system,* $\mathbf{K} \subseteq \mathbf{S}$.

The informative space **I** in real conditions is fully observable and therefore it is covered by some information set *I* containing the sets *U* and *X* available for measurement. In this case, the set *I* is a collection of vectors $\vec{\mathbf{u}}(t) \in U \subset \mathbf{U}$, $\vec{\mathbf{y}}(t) \in Y \subseteq \mathbf{X}$, observed on **J**,

$$\mathbf{I}_e = \{\mathbf{U} \in \mathbf{R}^m, \mathbf{Y} \in \mathbf{R}^n \mid \vec{\mathbf{u}}(t), \vec{\mathbf{y}}(t), t \in \mathbf{J}\}. \quad (5)$$

Since the elements of *I* are obtained in the process of measuring the observed state variables, the set *I* contains only numerous images of the elements of the spaces **U** and **X**. To fully characterize an object, set *I* includes a priori information, so **I** is represented in the form

$$\mathbf{I} = \{\mathbf{I}_a, \mathbf{I}_e\}, \quad (6)$$

where: $\mathbf{I}_a$, $\mathbf{I}_e$ *– a priori and experimental information, respectively.*

Information set **I** is used to identify control objects *(6)*. The structure and properties of the set $\mathbf{I}_e$ greatly influence the choice of the method for synthesizing the mathematical model and the type of the parameter estimation algorithm used. Information $\mathbf{I}_e$ has the form *(5)* and includes the results of measurements of both input and observed (output) state variables and indirect parameters depending on the output variables [3].

Depending on the identification problem being solved, the set $\mathbf{I}_e$ can have a different structure. If the problem of one-time identification of the control object is solved, then the measurement process has a fixed end t_e, and $t_e > t_0$, where t_0 is the start time of observation. In this case, information $\mathbf{I}_e$ has the form *(5)* and is represented in the form

$$\mathbf{I}_e(\mathbf{J}) = \{\mathbf{H}_U(\mathbf{J}), \mathbf{H}_Y(\mathbf{J})\},$$

where: $\mathbf{H}_U(\mathbf{J}) = [u(t_0), u(t_1), \ldots, u(t_e)]$, $\mathbf{H}_Y(\mathbf{J}) = [y(t_0), y(t_1), \ldots, y(t_e)]$ *– matrices of the corresponding dimensions.*

If the current identification is performed, then the information $\mathbf{I}_e$ has the form

$$\mathrm{I}_e = \{\vec{\mathbf{u}}(t), \vec{\mathbf{y}}(t)\},$$

where: $t = t_0 + (i - 1)\tau$, $i = 1, 2, \ldots$, t – current moment of time; τ – data reading interval.

With the current identification, *i* grows indefinitely as the time of operation of the object increases.

Thus, the set $\mathbf{I}_e$ in specific applications has a different form. Information $\mathbf{I}_e$ contains data on the parameters and characteristics of the object and the limits of their measurement. Implicitly, $\mathbf{I}_e$ displays the constraints on the parametric space of the processes occurring in the object. Therefore, the set $\mathbf{I}_e$, having the form of a digital array, can have a rather complex structure. The element $w(t) \in \mathbf{I}_e$ can be represented as [4]

$$w(t) = w_c(t) + w_g(t) + w_x(t) + \xi(t),$$

where: $w_c(t)$ – constant or arbitrarily varying function; $w_g(t)$ – harmonic function with fixed period; $w_x(t)$ – some process; $\xi(t)$ – measurement interference.

The component $w_c(t)$ reflects the main operating mode of the object, and $w_g(t)$ – any periodic phenomena and processes also associated with the main process. Functions $w_x(t)$ and $\xi(t)$ reflect the influence of various disturbances: $w_x(t)$ characterize internal, and $\xi(t)$ external influences.

The set $\mathbf{I}_e$ will not always have such a structure. Depending on the properties of the object, some of the components of *w* may be absent or have a more specific form, that is, the function $w(t)$ can be written as

$$w(t) = w_s(t) + \xi(t),$$

where: $w_s(t)$ – a function that displays the structural features of an object; $\xi(t)$ – environments.

Conclusions. The processes $w_s(t)$ and $\xi(t)$ can have both stochastic and regular structures. In the case of a regular structure, various descriptions are used that allow an algorithmic representation. In the case of a stochastic nature of the processes, various static and probabilistic characteristics are used to represent $\xi(t)$.

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