Intellectualization of information processing systems for monitoring complex technical objects and systems

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Abstract. Creating intelligent information processing systems for monitoring complex technical objects and systems is an important task today. This paper presents the principles and models for creating systems of this class. The decision-making process in intelligent information-measuring monitoring systems is described. The article presents a model of intelligent monitoring system and a model of decision-making in intelligent monitoring systems. The presented model of decision-making in intelligent monitoring systems allows estimating the efficiency of their functioning. The article proposes a structural scheme reflecting the sequence of decision-making tasks.

Keywords: intellectualization, monitoring, information-measuring system, complex system, decision-making.

1. Introduction

The analysis of the main trends in the development of modern industrial facilities shows that they have a number of features. These are multidimensionality and uncertainty of their behavior, hierarchical organization of elements and subsystems, structural similarity and redundancy of the main elements and subsystems, the links between them, multivariant implementation of management and control functions at each level of the hierarchy, territorial distribution of elements and subsystems.

Increasing the level of complexity of a technical object requires a significant increase in the number of monitored parameters, characterizing the processes of its functioning [1-4]. In responsible applications, the number of controlled parameters already today reaches several hundreds and thousands. Such applications include rocket-space, aviation, ship technology, nuclear, thermal and hydroelectric power plants, power supply systems, radio-electronic and automated systems and complexes of various purposes, infrastructure objects [5-9].

Time delays and errors in management caused by incorrect solutions to the task of assessing or monitoring the conditions of industrial facilities can lead to irreversible negative consequences -

failure of the tasks assigned to them, failures, accidents and even disasters of various consequences. This can create a threat to life and health of people, lead to environmental disasters or significant material damage [10-12].

This problem is exacerbated to the greatest extent when abnormal situations occur - deviation of the behavior of industrial facilities from the expected behavior caused by various external and internal factors. As a rule, the procedures of monitoring the condition of industrial facilities are not automated.

The solution of this task is entrusted to operators, which introduces the so-called human factor into the work of information-measuring systems. Practice shows, that it is in these situations operators do not cope with the task of assessing and monitoring the functional states of industrial facilities, which leads to various negative consequences.

All this does not allow receiving acceptable characteristics of functioning of information-measuring monitoring systems and, hence, to provide successful realization of all functions of measurement, control, diagnostics and identification of parameters of industrial objects by classical methods.

The monitoring systems working with the information represented in the digital form have significant advantages over the systems working with analog signals. However, such systems are not able to adapt independently neither to changes of structure or dynamics of the object, nor to influence of external operational factors.

The solution of such problems is impossible without application of intellectual methods of information processing. One of the most important tasks of intellectual information-measuring and control systems is to provide autonomous functioning of the system in conditions of incompleteness and uncertainty of incoming information in the presence of random perturbations of the external environment.

2. Application of Artificial Intelligence in Monitoring Systems

The main functions of intelligent systems are event prediction, self-learning and adaptation, work with knowledge bases (including formation, structuring, storage, as well as database content exchange operations), formation of decisions and their execution.

The choice of methods and technical means of implementation of intelligent systems is a separate issue, solved on the basis of the specifics of a complex technical object, the experience of developers and the availability of material, human and time resources.

Application of artificial intelligence in monitoring systems allows expanding functional capabilities of the system, to increase accuracy, efficiency, reliability and to improve other characteristics and parameters because of fulfillment of certain requirements to the system and solution of the following problems:

- carrying out multichannel measurements with high accuracy, collection of information from measuring transducers (sensors), automation of research and testing, calibration and verification of sensors, control of environmental parameters in production processes;
- performing a sequence of measurement procedures and processing of primary information, making decisions and presenting the results in a digital form;
- ability to synthesize an algorithm for the functioning of intelligent monitoring systems in the current situation;
- identifying information about the environment, adapting to the effects of external and internal destabilizing factors;
- solving the problem of prompt and systematic replenishment of the knowledge base;
- providing high speed of calculations, optimization, decision-making, forecasting and modeling of measurement results in real time in the system.
- Transformation of the measuring information in the digital form which provides high noise immunity at transfer of signals, stability of parameters processing, independence from time and influence of changes in the environment, action of destabilizing factors;
- Provision of system flexibility because of capability to rearrange structure of hardware, measuring and controlling functions by means of software;
- Realization of a modular principle of designing on the basis of the modern open standards, possibility of modernization by installation of the required modules and replacement of the applied software, maintenance of work in various conditions: in the workshops of the enterprises, in scientific laboratories, at remote access, in field conditions under the influence of external destabilizing factors;
- development of the software, carrying out primary mathematical processing of the information according to the set formulas and approximating dependencies, transfer of results of measurements in a local network of the enterprise during measurement of parameters of object of monitoring, formation of a knowledge base in system
- processing of the received data arrays by means of specialized application software packages for solution of problems of forecasting, identification and management of measurements, transfer of measurement results to computing system, their saving, viewing, analysis, and also printing of the selected results in the form of tables with time and date indication of measurement and control of object parameters.

The need for intelligent monitoring systems also arises when the subject area, e.g., the physical nature of the monitoring parameters, is constantly evolving. Therefore, the basis of such intelligent systems is a constantly developing model of the subject area based on a continuously updated knowledge base.

In this regard, intelligent information-measuring systems (IIMS) should have a created knowledge base, adequately reflecting information about the subject area and be adapted to restructure hardware and software in accordance with the chosen strategy.

There are many strategies for monitoring in different operational situations $S = \{S_b, S_p, S_s\}$, where S_b — identification of parameters measured or controlled by intelligent monitoring systems under the influence of destabilizing factors;

S_p — parametric correction of the basic algorithms of intelligent monitoring systems depending on the changing situation;

S_s — structural correction, involving the choice of given algorithms for the functioning of intelligent monitoring systems.

The strategy of identification S_b, involves the collection of information about the characteristics of a complex technical object at the stage of preparing and conducting tests of the system under the influence of destabilizing factors. The destabilizing factors affecting the performance of intelligent monitoring systems are ambient temperature, humidity, pressure, the level of electromagnetic field strength, radiation background. This strategy together with the knowledge base of intelligent monitoring systems is used to establish the deviation of system parameters from those introduced during testing, and about the parameters under normal operating conditions available in the knowledge base.

At correction on parameters strategy S_p, adaptation of algorithms of functioning of intellectual monitoring systems, parameters of object and results of measurements is carried out. During the correction, it is possible to change the measurement algorithm depending on the measurement situation, the degree of thermal or electromagnetic influence, and their range. The correcting strategy makes it possible to obtain more accurate results in the process of operation of intellectual monitoring systems without resorting to a fundamental change in the algorithm and operating principles of the system.

Structural-corrective strategy S_s defines an algorithm of functioning of intellectual monitoring systems and assumes rearrangement of structure and software of intellectual system depending on the current situation, Application of information technologies, development of principles of construction of information and measuring systems allows synthesizing structure of IIMS of monitoring of industrial objects in conditions of uncertainty and influence of external factors.

3. Decision-making process in intelligent information and measurement monitoring systems

When making decisions in the IIMS, at each stage of operation there is an analysis of the achievement of the set goal. If the goal is not achieved, then new solution options are considered, and the decision process is repeated, taking into account the information obtained at the previous stage. Thus, optimal decision-making is reduced to the choice of such an algorithm for the functioning of IIMS, which will maximize the criterion of technical efficiency of the system, which depends on the strategy for finding optimal solutions.

Decision-making in intelligent systems makes it possible to evaluate the effectiveness of their functioning. Efficiency, according to this model, is defined as a function of variables describing the properties of the object, the conditions and methods of measurement, the structures of such systems, and the criteria for evaluating the results.

Decision-making in IIMS is aimed at the process of finding a solution to the measurement problem and determining the optimal measurement algorithm, search strategies, measurement procedures at each stage with a known division of information into deterministic, random and fuzzy.

In the functioning of the IIMS it is necessary to make decisions when considering the following tasks:

- formation and selection of the model of the object under study;
- control method;
- the choice of parameters of the measurement situation;
- assessment of quality and efficiency of the system.

When modeling the decision-making process in the IIMS, it is necessary to determine:

- model variables, methods of IIMS structure parameters, methods of metrological analysis, destabilizing factors and performance evaluation criteria;
- to formulate the requirements to the initial information about the studied objects, to organize obtaining of a priori and primary measurement information about the object, the analysis of the measurement situation, and the degree of influence of the destabilizing factors;
- to be able to assess the quality and efficiency of the process of functioning of the modeled IIMS need to choose a set of criteria for assessing the effectiveness in the function of the parameters and variables of the system, taking into account the destabilizing factors.

For the possibility of obtaining numerical values of the used characteristics of the system in the process of modeling, approximating functions are used.

Model evaluation is carried out on the basis of assessment of validity of stated model concepts. This method of validation includes the following procedures:

- verification of the tasks set;
- validation of initial information;
- verification of model construction, analysis of parameters of variables included in the structure of the IIMS model.

4. Model of decision-making tasks in intelligent monitoring systems

To achieve the goal in the IIMS - rapid, accurate and reliable determination of the properties of objects - a model with a formalized description of the decision-making process is proposed.

To build a decision-making model in an intelligent monitoring system, three components are required: the goal, the environment, and the internal state. Decision-making models in an intelligent system include:

- formation of the structure and algorithms of functioning of intelligent monitoring systems as a whole;
- development of structure elements, algorithms of their functioning;
- mechanism of interaction between themselves and with the environment;
- construction of information processing algorithms.

Assessment of the model is carried out on the basis of assessment of reliability of stated concepts of the model. Such method of verification includes the following procedures: check of set tasks; check of reliability of initial information: analysis of obtained approximations; check of model construction, analysis of parameters of variables included in the structure of intellectual MIS model.

Let us represent the model of the intelligent monitoring system as follows:

$$\{I, F, O, M, D\} ,$$

where I – set of input influences;

F – set of destabilizing factors;

O – set of output parameters;

M – set of applied intelligent methods;

D – set of decision-making methods.

Intelligent systems, that implement the decision-making function using the knowledge base, have the following requirements:

- accounting for the time factor in the search for a solution, obtaining reliable results with possible incomplete search, taking into account the loss of accuracy and timeliness;

- the ability to find the best solution when analyzing the accuracy of the results and the cost of computing resources to obtain it;
- the use of methods of inference, taking into account the time factor when using the information from external sources and contained in the knowledge base of the system;
- use of the latest information processing technology;
- high-level decision-making;
- ability to make decisions based on symbolic transformations;
- ability to identify the class of material under study, the subject area, the measurement situation, using the knowledge base;
- ability to synthesize measurement structures, evaluation of obtained results.

Decision-making model in intelligent monitoring systems is represented in the form of five, containing a set of measurement methods, measurement situations, structures and states of such systems and criteria for evaluation of measurement results:

$$\{M, S, C, B, A\},$$

where $M = \{M_i, i = 1,2, \dots, m\}$ — set of methods used;

$S = \{S_i, i = 1,2, \dots, s\}$ — set of measuring situations;

$C = \{C_i, i = 1,2, \dots c\}$ — set of criteria for evaluating measurement results;

$B = \{B_i, i = 1,2, \dots, b\}$ — set of initial system states;

$A = \{A_i, i = 1, 2, \dots, a\}$ — set of algorithms for the operation of intelligent monitoring systems.

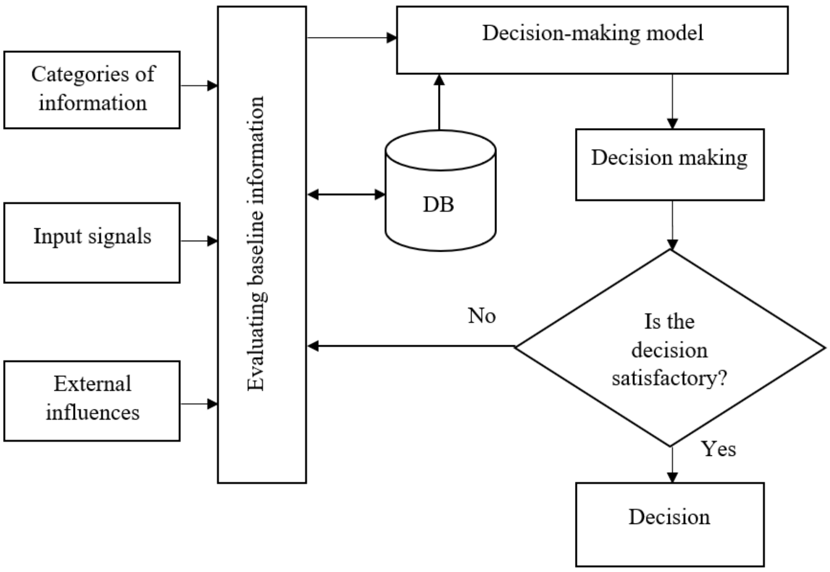

Figure 1. Sequence of decision-making tasks.

The decision-making model used in such systems makes it possible to evaluate the performance of the system. It operates with the properties of intelligent methods, conditions and methods of measurements, taking into account the structure of intelligent monitoring systems, the choice of measurement procedures, criteria for assessing the results of measurements. The structural scheme reflecting the sequence of decision-making tasks is presented in figure 1.

5. Conclusion

Decision-making in intelligent monitoring systems is aimed at selecting the task of determining the optimal measurement algorithm, measurement procedures at each stage. It includes making decisions on belonging the relative error of measurement results to the range of permissible relative errors; making decisions on performing classification of intellectual methods on the basis of defining losses from misclassification, making decisions on loss of accuracy and operability; making decisions on assessing the reliability of the decision made.

Intellectualization of complex technical objects monitoring systems will allow increasing their reliability, creating systems corresponding to the level of complexity of the technical system. Application of the IIMS will reduce the likelihood of situations resulting in irreversible negative consequences.

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