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THE ACCURACY IMPROVING OF MODELLING OF FIREFIGHTING PROCESS IN THE INFORMATION SYSTEM OF FIRE SAFETY MONITORING

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Abstract

In order to improve data processing efficiency in technology of multilayer fire safety monitoring multilayer models of fire fighting process characteristics are proposed for use as algorithms of information form transformation (AIFT). Method of multilayer synthesis based on hierarchic combining of models of one object into integrated AIFT allows to compensate low informational content of input data through formation of effective connections between indices.

Keywords: informational system, monitoring, fire fighting, multilayer synthesis, algorithms of information form transformation.

INTRODUCTION

Formulation of the problem. Implementation of the comprehensive research-backed management system (involving all organizational levels) that would be based upon unbiased data from the appropriate monitoring systems, including, inter alia, the fire safety monitoring system, is considered to be one of the available optional conditions for sustainable development of the society. In terms of informational support, the fire safety monitoring system shall provide for organization of the required data streams and enhance the observation over basic processes and events associated with prevention of fires and operative responses for the purpose of fire suppression and elimination the consequences thereof. The essential prerequisite for making sound management decisions is the availability of proven informational support enabling to obtain various trend data that outline the actual fire safety status. At the same time, all adverse trends occurring in the course of complicated 'Man-Society-Nature' system development lay stress upon increased significance of the fire safety status monitoring.

Researches conducted by numerous domestic and foreign scientists in the field of the applied fire safety monitoring and resolution support systems development, organization of the information & analytical support and fire extinguishing processes modeling have provided for creation of the appropriate theoretical and methodological basis applicable to system-oriented analysis, fuzzy-set theory, automated control systems, applied statistics and resolving methodology.

Identification of the management target object is considered to be the milestone phase of the monitoring systems development. The said task requires the construction of model upon results of the observation over its functioning. The structural identification involves determination of the structure and type of the target object operator, or that is to say the type of the target object mathematic model.

There are three methodological groups that could be conditionally distinguished among the existing structural identification problems solving methods. Each group defines one of the main structure selection approaches, in particular, the *Classical, Modern* and *Non-conventional* ones [1].

The *Classical* structural identification problems solving method is based upon statistical hypotheses verification system and described in works of P. Eickhoff [2], L. Ljung [3] and other authors.

The *Modern* approach to selection of the structure involves implementation of the model complexity / precision trade-off principle (regarding the number of parameters being estimated); the most common directions therein are matured by C. Mallouse [4] (*Unbiased Estimation of the Model Theoretical Error*), V. Vapnik [5] (*The Average Risk Guaranteed Estimate*), etc.

The *Non-conventional* 'cross-substantiation' approach is based upon division of the sample data for the purpose of getting the additional information on the assumption of inadequate information value of the input data arrays. It is mainly contributed by O. Ivakhnenko [6] (*Group method of data handling [GMDH]*) and J. Tukey [7] (*The Jacknife Method*). Due to the efficiency in the time of solving wide range of problems connected with identification,

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prognostication and recognition, methods involving sample data differentiation, in particular the GMDH, have recently given rise to significantly increased interest.

The functional identification tasks shall be understood as estimations of the unknown coefficients of the target object mathematic model equation for the purpose of matching the model and target object outputs. The functional identification task may be formulated as follows. Let us assume that fully observable and controllable object is defined via the equations of state:

$$\begin{aligned} \frac{dx}{dt} &= Ax + Bu\ ; \\ y &= Cx\ ; \\ x(t_0) &= x(0)\ ; \end{aligned} \qquad (1)$$

where B – is n-dimensional column-vector, C – is n-dimensional row-vector, A – is n x n square matrix. Elements of A, B and C vectors are unknown quantities. Identification just stands for determination of such quantities.

Therefore, we are faced with a problem related to development of advanced information technologies required for solving tasks of the firefighting operations control to be based on statistical data obtained upon reporting of the fire brigades conduct in the time of fire suppression. The range of problems inherent to the issue under review comes down to the lack of information value of the fire reporting data arrays that is conditioned by numerous errors depending upon human factor, and as well by unreasonable structure of the database contained figures.

Analysis of the recent researches and publications. As the information basis for the research, there have been used statistical data of the State Fire Safety Department of the Ministry of Internal Affairs of the USSR and subsequently, the appropriate units of the Ministry of Internal Affairs and the Ministry of Emergency Response of Ukraine.

The tasks related to the fire brigades operating control are particularly reviewed in works of V. Matiushyn. It is stated there that the most domestic publications are mainly dealing with imitation modeling of the emergency calls number and application (in the time of modeling) of the public service systems used for determination of probabilistic characteristics of the fire brigades performance. According to N. Brushlinskyi, the frequency of emergency calls is mainly dependable upon time factor, while the number of such emergency calls is a linear function dependent on density of population.

The aforesaid and other authors lay stress upon poor precision of the existing mathematic models that is conditioned by inadequate number of factors taken into account, equivocation of values thereof, complexity of verification, whatsoever.

Identification of previously unsolved issues being the parts of common problem. Having reviewed the research dedicated bibliographic sources it is possible to make a conclusion that the vast majority of publications deals exclusively with researching specific features of substances, their combustion processes and modeling of the fire spread situations. Overseas developed program systems, such as FPETOOL, HAZARD-1 and FIREFORM, are oriented to modeling of the fire escalation inside buildings.

The system-oriented analysis of the fire patrol operations in the Ukrainian cities shows the lack of the information & analytical support of the fire brigades. The existing systems mainly stand for solving of management staff tasks and are based upon methods of statistical information analysis, thus often preventing from justification of the quantity and availability of the resources. The information subsystem is intended for ultimate emergency calls handling rather then achievement the call target being furthermore even not formulated yet. The justification of the number of fire departments, number and types of the fire-fighting media is made without taking into account the specific features of the facilities and areas representing the main aspects of the analytical subsystems.

The system-oriented approach to removal the aforesaid shortcomings and as well to solving of the many other problems is based upon setting the logic scope of tasks for fire-watch system as solid structure actively and continuously interacting with the environment, by virtue of which there will be defined the peculiarities of the fire safety monitoring system project development.

Therefore, we are faced with a problem of the fire safety monitoring that in terms of modern sense, may be considered as analytical & information system involving the following main directions:

1) observation over fire safety condition and factors affecting certain aspects thereof;

2) estimation and review of the actual status of all fire safety components;

3) prognostication and assessment of the fire safety condition;

4) providing the scientific & information support for making management decisions.

Objective statement. Review of methods for selection of the solution for the fire safety information monitoring has shown inefficiency of the conventional approaches. In order to solve tasks of the fire safety monitoring it shall be necessary to implement the up-to-date information & analytical technologies, in particular argument group accounting method based upon recursive and selective sampling of the models used as basis for creation of more complicated ones. The accuracy of modeling and prognostication, as well, is subject to improvement with every passing recursion stage (as the model becomes more and more complicated), thus being of specific relevance for the fire safety provision.

EXPOSITION

Technology of multilayer monitoring of fire safety [8] is formed through the method of creation of information systems of multilayer monitoring [9] and provides multilayer transformation of numeric characteristics of objects and fire fighting divisions to provide information for processes of fire safety control of specified administrative region.

Number of levels of information transformation is defined via expert analysis according to the assigned task. Technology has several steps. During a preparation step structure is formed of global function of information transformation in the form of a hierarchic combination of inductive models of monitored objects of corresponding level. During a testing step global function is being tested on data array formed during the last time period and a conclusion is made concerning capability of usage of this

system for operative information transformation at the next step. During a step of operative information transformation results of monitoring of fire inspection objects are transformed into the form of characteristics of factors' influence and prognostic losses characteristics arising as a consequence of emergency situations in the overall administrative region.

During use of this information technology for solving new tasks of operative control of fire fighting process it was found that low informational content of input data arrays formed on the base of standardized list of fire fighting characteristics is insufficient for synthesis of high-quality models used as AIFT. Contradiction were found between the need of increase of informational value of input data and possibility of getting such data, which is limited by standardization of characteristics which are promptly registered during a fire fighting process.

In this work one task is being solved for fixing problem mentioned – increasing of power of tools for models synthesis which should provide desired quality of these models.

It's necessary to provide structural-functional identification of following relationship:

$$y_i = f\left(X, C\right), i = 1, ..., k, \qquad (2)$$

where y_i – fire fighting process characteristics which is being modeled;
k – number of characteristics for modeling;
X – range of state characteristics of object with fire outbreak $X = \{x_1, x_2, \ldots, x_n\}$, where n – number of characteristics;
C – range of resources needed for fire suppression $C = \{c_1, c_2, \ldots, c_m\}$, where m – number of resources types under conditions:

$$S_y = \sqrt{\frac{\sum_{i=1}^{k}\left(y_i - y_i^*\right)}{y_i^*}} \to \min, \qquad (3)$$

where y_i^* – actual value of characteristics being modelled.

To provide necessary diversity of tools for models synthesis reflecting functional relationships (2) in the conditions of insufficient informational content of input data set method of multilayer model synthesis is proposed [10].

By hierarchic combining of input data indices multilayer modeling allows to reflect in model information of input data set which earlier was inaccessible.

Based on the results of solving of the problem of structural-functional identification a multilayer polynomial model is obtained containing other models of one object which were synthesized using finished algorithms.

To assess effectiveness of multilayer modeling an experiment was conducted. The aim of modeling was identification of functional relationship between time of fire extinguishing and normal indices of fire fighting.

In Table 1 a list of standard indices is shown on the basis of which an array of input data (AID) was formed.

Table 1.

#	Index	Variable
1.	Day of call	x_1
2.	Month of call	x_2
3.	Year of call	x_3
4.	Number of floors	x_4
5.	Floor	x_5
6.	Fire resistance code	x_6
7.	Time of fire start	x_7
8.	Time of call	x_8
9.	Time of arrival	x_9
10	Time of localization	x_{10}
11	Clearing time	x_{11}
12	Circumstances contributing to fire expanding	x_{12}
13	Circumstances complicating fire fighting	x_{13}
14	Fire fighting participants	x_{14}
15	Number of fire fighting participants	x_{15}
16	Machinery	x_{16}
17	Quantity of machinery	x_{17}
18	Fire-fighting hoses	x_{18}
19	Fire-fighting hoses presented	x_{19}
20	Fire extinguishing agents	x_{20}
21	Fire fighting primary means	x_{21}
22	Water source	x_{22}
23	Fire fighting head	x_{23}

Model quality was assessed by mean relative error of modeling observations when checking sequence of input data set:

$$\delta = \frac{\sum_{i=1}^{n}\delta_i}{n}, \qquad (4)$$

where n – number of observations in checking sequence;
δ_i – relative error of modeling y_i individual observation in checking sequence of AID.

Figure 1 shows results of multilayer synthesis method testing in the process of structural-functional identification of functional relationship (2).

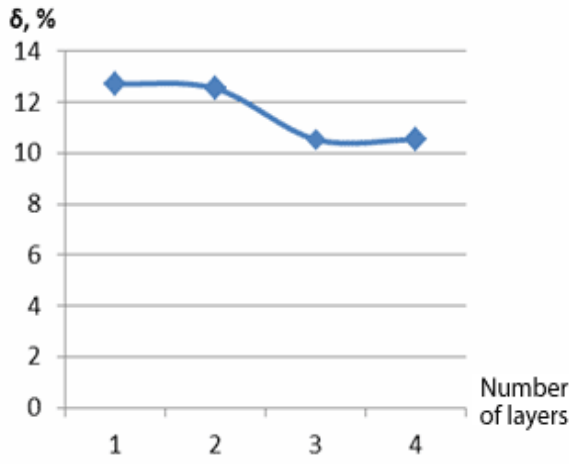

Fig. 1. *Relative model error by layer*

CONCLUSION

In summary, problem of synthesis of high-quality models providing information for operative fire fighting control can be solved with the help of a method of multilayer synthesis of these models which is able to ensure their adequacy under the conditions of low informativity of AID.

Experimental confirmation was got of effectiveness of use of method of multilayer modeling. Mean modeling error in the test on the checking sequence decreased by 17.28%.

Prospects of the further researches in the field concerned. The subject matter of the future researches is a dependence of factors leverage capabilities upon a number of the model tiers. The results of factors significance verification shall be used for working out the measures to be taken for improvement of the fire-fighting process efficiency in order to enhance the fire safety monitoring information technology.

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