Conference Paper

Information and Analytical Support for Management of Fire Extinguishing at Highly Dangerous and Technically Complex Facilities

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Abstract

In this article the authors formulate the task for process management of man-made fire extinguishing at highly dangerous and technically complex facilities. This task consists of fire localization and elimination using minimal assignment in minimum amount of time. For this task the authors developed a neuro-fuzzy model for fire extinguishing process control, the main elements of which are a neuro-fuzzy model for predicting the fire area, a neuro-fuzzy model for selecting the fire rank, a neuro-fuzzy model for evaluating the implementation success of the plan, a neuro-fuzzy model for selecting the optimal action plan, an analytical model for evaluation of resources sufficiency, an analytical model for resources selection, and a model for implementation of neuro-fuzzy models. In comparison with existing models, distinctive features of the developed model are the following: application of combined (bell-shaped with thresholds) membership functions that allow to perform more accurate approximation of input parameters values; implementation of the block to eliminate dynamic errors. This paper assesses model adequacy through verification and validation. The authors developed a system for fire extinguishing process control. This system allows us to raise of firefighters' efficiency due to increase of accuracy of managerial decisions taken by the manager and time reduction needed to formulate a decision.

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1. Introduction

During the statistics analysis [1] it is established that at present the task of providing facilities with fire safety by concentrating efforts on preventing, eliminating and minimizing fire effects and improving state administration, remains relevant.

Accidents in the territories of highly dangerous and technically complex facilities are of particular risk for economy, foreign trade and population. Solution of the task of providing these facilities with fire safety is possible by improving the forms and methods of management support of operation of controlled facilities. This improvement is possible by using modern methods and approaches based on information technologies.

According to [2] preference using of neuro-fuzzy networks for set task decisions is revealed. This makes it possible to determine modification need for existing approach of organization of fire extinguishing under complex circumstances. For the purposes of providing support of the managerial decision-maker under uncertainty it is proposed to develop a system of information and analytical support for fire extinguishing management based on neuro-fuzzy networks. Application of this system is aimed at providing the possibility of solving a poorly formalized control task for fire extinguishing under complex circumstances.

Thus, the objective of this scientific research is the development of system of information and analytical support for management of fire extinguishing at highly dangerous and technically complex facilities based on neuro-fuzzy networks to raise efficiency of fire departments.

2. A task of fire extinguishing process control under uncertainty

Function of the decision-maker plays a key role in management of actions of fire departments in organizing fire extinguishing under complex circumstances. This function represents totality of manager's decisions during required time that ensure successful fire extinguishing. Rational management, carried out by the manager, allows directing actions of departments to implement a single strictly defined goal, achieved by the tasks execution set by the manager. Effective management of forces and means in case of fire extinguishing reduces time of fire localization and elimination, reduces the amount of financial damage and significantly reduces social losses.

Formally, the task of process controlling of fire extinguishing under complex circumstances can be represented in the form, known from [3] of an ordered set of elements, the tuple K:

$$K = \left\langle Y, D_y, Z, D_z, S_a, S, W, T \right\rangle, \tag{1}$$

where Y is a set of considered controlled factors;

$D_y \subseteq Y$ is a set of actions of dependent fire protection resources involved in fire localization and elimination;

Z is a set of considered uncontrolled factors;

$D_z \subseteq Z$ is a set of actions performed by the manager's resources and cooperating types of fire protection;

$S_a$is desired outcome of the controlled process;

S is a set of possible states of the controlled process;

W is a set of criteria of management effectiveness;

T is a management purpose.

In accordance with [3], the task of fire extinguishing process control at highly dangerous and technically complex facilities is the task of managing a complex system under uncertainty. According to [2] it is impossible to use modern programs for the first line support of the manager in case of fire extinguishing in the context of information uncertainty. In connection with it there is a necessity to modify existing treatment of fire extinguishing organization in conditions of uncertainty. To this end, it is proposed to develop and implement a system of information and analytical support for management of fire extinguishing under complex circumstances based on neuro-fuzzy networks.

The analysis of managerial function of the decision-maker during fire extinguishing at highly dangerous and technically complex facilities is carried out.

The task of fire extinguishing process control at these facilities is formulated in the form of the system (2):

$$\begin{cases} \sum_{i=1}^{n} R_i \underset{t_j \to \min}{\longrightarrow} \min \\ 1 \le i \le 5 \\ j \in \overline{0, N}, j \in N \end{cases}, \tag{2}$$

where R_i is the fire rank, which determines the composition of forces and means, involved in fire extinguishing;

t_j is time of fire extinguishing in case of involvement into fire extinguishing of the certain complex of forces and means, min.

That is necessary to determine the fire rank that satisfies the system (1), and indicator value characterizing the fire extinguishing process (fire extinguishing time) must satisfy the system (1).

Thus, the task of fire extinguishing process control at the facilities in the context of information uncertainty is formulated. This task involves fire localization and elimination using minimal assignment in a minimum of time.

3. A neuro-fuzzy model for fire extinguishing process control at highly dangerous and technically complex facilities

For the purposes of fire extinguishing process control under complex circumstances a neuro-fuzzy model for fire extinguishing process control is developed (Figure 1), where U is input data; Z is output data; C is input data to build a neural network; M is the neuro-fuzzy model; S is the fire area; R is the fire rank; Q is the evaluating of resources sufficiency; P is the optimal action plan; W is the evaluating the implementation success of the plan; V is the resources selection.

This model in relationship with the external environment and the internal environment of the facility, shown in Figure 1, is considered in detail in [2, 4]. The main elements of this model are:

- a neuro-fuzzy model that indicates dangerous fire-flame factor by predicting the fire area and is based on ANFIS network (the structure of ANFIS network is described in [5]);
- a neuro-fuzzy model that determines the fire rank using NEFCLASS network (the structure of NEFCLASS network is presented in [6]);
- an analytical model that indicates sufficiency at the resource facilities engaged in fire extinguishing;
- an analytical model that determines the number of base and potential resources involved in fire extinguishing;
- a neuro-fuzzy model that implements selection of the optimal action plan for fire extinguishing through NEFCLASS network;
- a neuro-fuzzy model that determines evaluation of the implementation success of the action plan for fire extinguishing and is based on NEFCLASS network;
- a model that builds neuro-fuzzy models using NEFCLASS and ANFIS networks.

The neuro-fuzzy model for fire extinguishing process control has the following key features, in contrast to existing models:

- a neuro-fuzzy model is based on bell-shaped with thresholds functions of membership that allow more accurate approximation of the values of input parameters;

- a block for elimination of dynamic errors is applied in the model.

During verification and validation of the model for man-made fire extinguishing at the seaports (seaports are considered as highly dangerous and technically complex facilities), a simulation was performed. The simulation results are represented in [2]. In the course of evaluating the adequacy of model by means of application of simulation results, the adequacy of model is confirmed:

- it is established that models, obtained by using the model for implementation of neuro-fuzzy models, have higher factors of accuracy than basic ones due to the use of combined membership functions in models;

- for prediction of the fire area in case of fire extinguishing it is established that application of this model leads to the accuracy increase of simulation results due to the eliminating dynamic errors in simulation process;

- for fire rank selection in the course of fire extinguishing it is revealed that application of this model doesn't lead to the accuracy increase of simulation results due to the absence of dynamic errors in simulation process;

- for evaluation of the implementation success of the plan it is established that application of this model leads to the accuracy increase of simulation results due to the eliminating dynamic errors in simulation process;

- for optimal action plan, it is revealed that application of this model leads to the accuracy increase of simulation results by eliminating dynamic errors in simulation process.

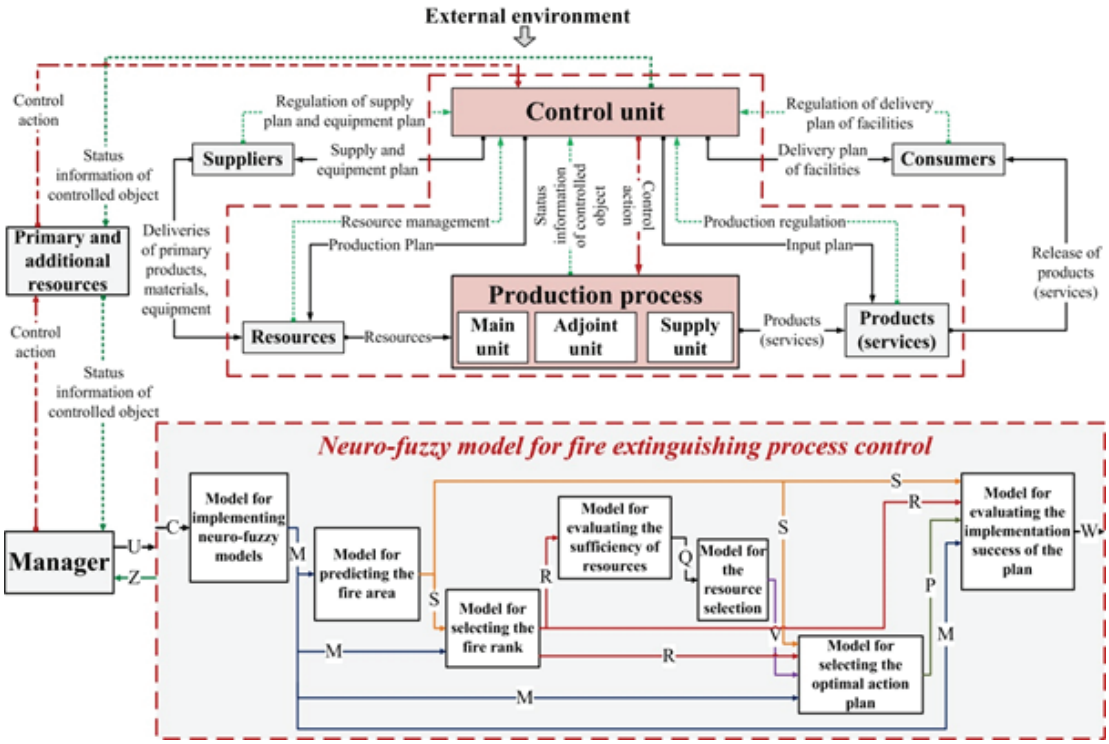

Figure 1: A neuro-fuzzy model for fire extinguishing process control at highly dangerous and technically complex facilities.

Thus, a neuro-fuzzy model for fire extinguishing process control is developed, which includes the following components: a neuro-fuzzy model for predicting the fire area; a neuro-fuzzy model for selecting the fire rank; a neuro-fuzzy model for evaluating the implementation success of the plan; a neuro-fuzzy model for selecting the optimal action plan; an analytical model for evaluation of resources sufficiency; an analytical model for resources selection; a model for implementation of neuro-fuzzy models. This neuro-fuzzy model is based on bell-shaped with thresholds functions of membership and presence of the block for elimination of dynamic errors.

4. Development of system of information and analytical management support for fire extinguishing at highly dangerous and technically complex facilities (using seaports as an example)

To improve fire extinguishing process control, expansion for automation of the process control is proposed that consists in development of information and analytical support system. During development of the system, purposes and tasks of the system are systematized, its effective structure is developed. Its main elements are defined: an object module containing mathematical models and controlling them to provide data exchange between system blocks; a control module that informs personnel of fire departments about results of the functioning of the object module.

In this work the program product is built – a system of information and analytical management support for fire extinguishing at highly dangerous and technically complex facilities. During creation of the program, unification requirements, organization specifics of firefighting tactics and practical aspects of application of program feature are taken into account and described in [2]. Three-tier architecture of the program is provided for adaptation implementing, characterized by speed and efficiency, and fast introduction of the developed system into information environment of the object. Also this architecture of the program makes it possible to the task management, taking into account manager's preferences. For system implementation Matlab and Delphi programming environments are used.

Evaluation of system efficiency is performed. Based on evaluation results of efficiency, considered in detail in [2], it is established that application of the developed system allows:

- increasing efficiency of managerial decisions of the manager (when predicting the fire area – in 2.5 times; when selecting the fire rank – for 29%; when selecting the optimal action plan – for 18%; when estimating the implementation success of the plan – 7%);
- reducing time input for decision-making by the manager (on average of 40%).

At present, the developed system is designed for information and analytical support for fire extinguishing management in seaports. State registration of the developed program products is performed [7, 8]: No. 2012618426 "Classifier of fire ranks" and No. 2013661903 "Intellectual decision support system based on fuzzy neural networks for fire extinguishing manager in the territory of "Kaliningrad Commercial Seaport" OJSC".

Implementation of results of the scientific study is performed in practical activities of "Spasatel" Limited Liability Company and fire and salvage unit No.17 on protection of Svetlogorsk municipal district.

Thus, the system structure and corresponding program product for the manager is developed. Application of the developed system in manager functions during fire localization and liquidation at highly dangerous and technically complex facilities makes it possible to increase efficiency of fire department operations. Also application of this system makes it possible to reduce time input in conditions of uncertainty under dynamic operational environment that in turn allows reducing time of fire localization and liquidation and number of deaths in case of fire.

5. Conclusion

In the course of scientific study the following results are obtained:

1. A neuro-fuzzy model for process control of man-made fire extinguishing is developed. Advantage of the developed control model, unlike existing ones, is using of bell-shaped with thresholds functions of membership and presence of the block for elimination of dynamic errors. Bell-shaped with thresholds functions of membership make it possible to approximate input values of the model more accurately, in comparison with basic standard functions. The block for elimination of dynamic errors neutralizes dynamic errors that arise during functioning of the model.
2. Adequacy of developed algorithms is evaluated by implementing verification and validation. The results obtained under simulation confirm adequacy of the algorithms.
3. Taking into account unification requirements, the system of information and analytical management support for fire extinguishing at highly dangerous and technically complex facilities is developed. Efficiency of this system is evaluated and increase of efficiency factors of fire extinguishing managers' decisions is proved. Accuracy and correctness of managerial decisions increases. Time input for decision-making by the manager decreases.
4. Theoretical significance of scientific results is justified by the fact, that obtained model develop a theoretical and methodological basis for operational predicting of fire development parameters and making managerial decisions under uncertainty. Practical significance of research results consists in possibility of using

developed system in process of developing pre-planning documents for organization of firefighting tactics as well as in process of coordinating fire department actions in course of fire extinguishing.

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