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THE CONCEPT OF CREATING AN INTELLECTUAL CORE OF AN INTEGRATED INFORMATION AND ANALYTICAL SYSTEM FOR ACTION IN EMERGENCIES OF MAN-MADE NATURE

Subject matter. Informatization of processes of counteraction to man-made emergencies. **Goal.** Improving the effectiveness of the process of information support for decision-making in overcoming the consequences of man-made emergencies, in terms of its intellectualization, by creating a concept of integration of various software tools within a single, homogeneous space of knowledge about strategic, tactical and operational actions in a wide range of accidents and disasters related to the operation of technical facilities. **Tasks.** Develop a formal statement of the problem of decision-making in an emergency situation and justify the methodology of its implementation based on the integration of knowledge tools with various analytical models that describe the processes of emergency. Consider the application of the proposed methodology on a scenario that reproduces the situation on the site after the leakage of a highly toxic substance. **Methods.** System analysis - in the development of a comprehensive process model for decision-making in an emergency; software engineering - when creating the architecture of an integrated intelligent decision support system in emergencies of man-made nature; physics of the processes of distribution of toxic chemicals in the atmosphere - in the development of a scenario of the situation at the site in an emergency situation at an industrial site. **Results.** The concept of creating an integrated intelligent decision support system for overcoming the consequences of man-made emergencies, in particular, the formal formulation of a typical problem of decision-making in emergencies is described, as well as the basic principles of its solution, and the formulation of the problem of modeling management processes associated with man-made emergencies is developed. **Conclusions.** The concept of creating an integrated information-analytical system to support decision-making in man-made emergencies is presented. Within the framework of this concept, formal models of decision-making in man-made emergencies and an approach to the integration of diverse software within a single, homogeneous knowledge space on comprehensive measures to overcome the consequences of emergencies related to accidents and disasters at technical facilities infrastructure. The scenario example of the organization of intellectual support of decisions at release into the atmosphere of a toxic chemical is considered.

Keywords: man-made emergency; decision support; process model; integrated intelligent information-analytical system; toxic chemical.

Introduction

Decision-making processes for overcoming emergency situations associated with man-made accidents and disasters occur under conditions of high uncertainty caused by the absence or incompleteness and inaccuracy of the initial data, their ambiguity, and insufficient level of information and analytical support. The scale of damage from accidents and disasters at industrial and other infrastructure facilities determines the need to develop an integrated decision support system, in which traditional analytical methods and tools will be supplemented with intellectual means that can adequately reflect the expert experience presented in the form of production rules. Such an integration of means of different types by their nature will make it possible, on the one hand, with sufficient accuracy to reflect the current state of the decision-making object in an emergency situation, and on the other hand, to reduce the level of uncertainty when reflecting factors that are difficult to formalize.

Decision-making tasks related to control under ES conditions differ significantly, depending on the mode of operation of the decision-making object to which these tasks relate. It is customary to distinguish three types of tasks: ES warning tasks, which must be solved in normal operation modes of the object before ES appears; tasks of immediate response to the emerging ES; tasks of overcoming the consequences of ES.

Tasks of the first type involve the formation of resources and the implementation of activities that reduce the likelihood of ES. The solution of such problems requires preliminary material costs. An increase in these costs leads to a decrease in the likelihood of ES, so these tasks are actually tasks of risk management.

The tasks of the second type include the tasks of ES identification, the selection and implementation of protective measures that must be immediately carried out using the available resources, as well as the determination of the necessary additional resources to prevent the development and overcome the consequences of ES.

The third type covers the tasks of forming, and real-time implementation of the sequences of activities that are most appropriate to overcome the consequences of ES.

The tasks of the first type must be solved in advance, by developing and implementing appropriate programs and plans. In contrast, tasks of the second and third types, as a rule, appear suddenly and differ significantly from ordinary tasks. Such tasks must be solved in real time, taking into account the restrictions on the time of formation and decision-making, as well as the amount of available resources.

Tasks of the second type differ in that only available resources can be used to solve them, which do not require significant preparation time. In some cases, for solving problems of the third type, it is also possible to use resources, the preparation of which may take some time.

Formation of decisions in ES conditions is essentially reduced to the implementation of tasks of the second and third types. In this regard, it is advisable to present the formal formulation of the decision-making problem in ES as a set of decisions on the selection and implementation of activities (operations) that are sequentially performed in real time, depending on the state of the decision-making object and disturbing influences from the environment.

Formulation of a scientific problem and its meaning

The problem underlying this study is a consequence of the contradiction between the possibility of traditional, analytical methods and means to adequately represent both the processes taking place in ES conditions of a technogenic nature, and a set of measures to prevent, overcome and eliminate the consequences of such phenomena, and the need for such presentation for the development of information support tools for managers of various ranks in the formation of a set of relevant activities. At the same time, artificial intelligence and knowledge engineering tools provide the ability to create effective process models that adequately describe the manipulation of resources in the space-time continuum.

Thus, a solution to this problem can be obtained by creating a methodological basis, within the framework of the concept of special integrated intelligent decision support systems in the ES environment of a technogenic nature.

Analysis of publications on the stated problem

Modern foreign information and analytical systems (IAS) (Swedish IAS PRIO [1], IAS as part of the American EPA system [2], etc. [3-6]) are mainly aimed at modeling the spread of toxic chemicals (TCH) in atmosphere, while the organization of evacuation measures remain behind the scenes. Domestic systems are focused on calculating the TCH affected area according to standard methods [7], which gives only an approximate picture of the distribution of TCH concentrations.

Thus, it is relevant to develop the concept of a specialized information and analytical decision support system in ES of a technogenic nature, which is based on a set of models, each of which belongs to one of two classes - those that describe the dynamics of ES distribution and those that reflect the complex ES countermeasures (for example, the advancement of rescue units and changes in the population of the affected area). This IAS is capable, on the one hand, to predict the spread of TCH, and on the other hand, to form decisions on the evacuation of the population from the ES zone and organizational measures to localize and overcome the consequences of the ES itself.

The purpose of the article is to solve the problem of increasing the efficiency of the process of information support for decision-making in the context of man-made emergencies, in the aspect of its intellectualization, by creating a concept for the integration of different types of mathematical and software tools within a single, homogeneous space of knowledge about strategic, tactical and operational actions in a wide the spectrum of accidents and disasters associated with the operation of technical facilities.

Materials and study methods

The current state of the decision-making object in ES can be formally described in the form of a set of fulfilled conditions P_τ, and a set of activities T_τ that are performed at the moment τ in real time [8, 9].

Using the introduced designations, the processes of object management in ES on the time interval Δ_η can be written in the form:

$$\{P_\eta^{(n)}, \{P_\tau, T_\tau\}, \tau \in \Delta_\eta, P_\eta^{(M)}\}, \qquad (1)$$

where $P_\eta^{(n)}$ – set of conditions fulfilled at the initial moment of ES occurrence τ_0, $\tau_0 \notin \Delta_\eta$;

P_τ, T_τ – accordingly, a set of fulfilled conditions, and a set of activities (operations) that are performed at the current time τ;

$P_\eta^{(M)}$ – a set of conditions that determine the goal of management in ES, the fulfillment of these conditions ensures overcoming the consequences of ES;

η – index of a specific implementation of control processes in ES that arose for a given automation object under specific environmental conditions.

Depending on the available resources and actions of the decision maker (DM), for each pair $(P_\eta^{(n)}, P_\eta^{(M)})$ that determines the initial and final (target) situations at the facility, different alternative decision-making processes are possible in order to overcome ES.

To assess the quality of decisions made (sequences of decisions made); it is advisable to define efficiency criteria φ, for example, in the form of minimizing the cost of resources or time spent on overcoming ES.

Depending on the characteristics of a particular decision-making object, environmental criteria can also be applied, in particular, criteria for minimizing the undesirable impact of ES on the environment, or others.

The set T_τ of activities carried out in the current time τ is determined by the decisions made, which, in turn, depend on the set of necessary conditions P_τ.

The control process on the interval Δ_η of overcoming the consequences of ES can be described as a sequence of sets (2):

$$U_\eta = \{T_\tau\}, \tau \in \Delta_\eta . \qquad (2)$$

Obviously, for a given pair of sets $(P_\eta^{(n)}, P_\eta^{(M)})$ of a specific decision-making object, disturbing environmental influences on the interval Δ_η, and restrictions on the necessary resources $R_s, s \in S_\eta$, the value of the control efficiency criterion φ uniquely depends on the sequence

(2) of decisions made and implemented in order to eliminate ES.

Thus, the problem of efficient control of an object under ES conditions can be formulated in the form (3) of finding the optimal sequence U^0_η:

$$U^0_\eta = \arg\begin{pmatrix} \mathrm{opt}\,\varphi(U_\rho) \\ U_\rho \in U^*_\eta \end{pmatrix}, \qquad (3)$$

With restrictions:

$$P^{(n)} = P^{(n)}_\eta, \qquad (4)$$

$$P^{(M)} = P^{(M)}_\eta, \qquad (5)$$

$$R_s \le R_{s\eta}, s \in S_\eta, \qquad (6)$$

$$\hat{R}_q \le \hat{R}_{q\eta}, q \in Q_\eta, \qquad (7)$$

$$\tau_q \le \tau_{q\eta}, q \in Q_\eta, \qquad (8)$$

where U^*_η is a family of sequences of the form (2) that are possible for a given decision-making object and specific values of disturbing influences from the environment on a time interval Δ_η;

$P^{(n)}_\eta$ – the set of satisfied conditions that determine the initial situation at the decision-making object at the moment of ES occurrence;

$P^{(M)}_\eta$ – the set of fulfilled conditions that determine the desired situation at the decision-making object after overcoming the consequences of ES;

$R_{s\eta}$ – the largest amount of *s*-the type resources that can be used in ES control and do not need to spend time on their preparation;

$\hat{R}_{q\eta}$ – the largest amount of the q-the type resources that can be used in ES control after preparation for a time not less than $\tau_{q\eta}$;

S_η – a set of ordinal indexes of resource types that can be used in ES control without wasting time for preparation;

Q_η – a set of ordinal indices of resource types that can be used in ES control after preparation in a time not less than $\tau_{q\eta}$.

In real-life cases, the occurrence of ES should be determined by equation (4) based on site monitoring data. Therefore, equation (4) defines a separate task of the second type, which can be written in the form:

$$P_{\tau_0} = P^{(n)}_\eta, \eta \in H, \qquad (9)$$

where τ_0 – the moment of occurrence of ES, which is determined by the set of fulfilled conditions $P^{(n)}_\eta$.

Obviously, the index $P^{(n)}_\eta$ in (9) can be considered as the identifier of a specific ES. Then H is the set of ES types.

Thus, the ES control problem Ξ can be written in the form of three types of tasks:

- ES prevention tasks ξ_1;
- tasks of immediate response ξ_2 at the time of ES occurrence;
- tasks to overcome the consequences of ES ξ_3.

$$\Xi = \{\xi_1, \xi_2, \xi_3\}. \qquad (10)$$

Tasks ξ_1 are associated with the planning of ES prevention measures and are qualitatively different from the decision-making tasks directly in ES conditions. They were briefly discussed above,

Tasks ξ_2 provide:

- timely detection of ES based on equation (9);
- ES identification, i.e. defining ES type η using equation (9);
- defining the goal of overcoming ES in the form of a set $P^{(M)}_\eta$;
- determination of the amount of necessary and available resources $\{R_{q\eta}\}$, $s \in S_\eta, \{\hat{R}_{q\eta}\}, q \in Q_\eta$;
- implementation of urgent measures to protect and prevent the development of ES, as well as to prepare the necessary resources $R_s, s \in S_\eta$.

The tasks ξ_3 involve the search and implementation of a set of sequences of activities (2), the best for a given initial situation $P^{(n)}_\eta$ and an efficiency criterion in a certain ES, taking into account the resource constraints that ensure the achievement of the target situation $P^{(M)}_\eta$, i.e. solution of the task (3) - (8).

The stated formulation of ES-related decision-making problems is developed in general terms that can be interpreted for the subject areas of different objects. This makes it possible to consider problem (3) - (8) as typical for a wide range of problems related to decision support under ES conditions.

Described above, the formal formulation of a typical decision-making problem under ES conditions can be represented as a set of subtasks ξ_2 that must be solved immediately, and subtasks ξ_3, the solution of which is associated with the definition and sequential implementation of sets of measures (2) that best meet the specified criteria efficiency and constraints.

Tasks ξ_2 are distinguished by one-time formation of solutions. The solution of the tasks of this group is carried out by continuous monitoring of the current state of decision-making objects at the time of detection and identification of ES using equations (9). The process of solving tasks involves determining the target situation in the form of sets of conditions $P^{(M)}_\eta$, available resources $\{R_{s\eta}\}, s \in S_\eta$, a list of urgent measures to protect, prevent the development of ES and prepare the necessary resources $\{\hat{R}_{q\eta}\}, q \in Q_\eta$, as well as the implementation of these activities.

All solutions to these tasks must be obtained using production rules in the knowledge base (KB) or by reading data in database files (DB); corresponding to a specific ES.

In contrast, tasks ξ_3 for their solution need to be concretized and implemented in real time by a sequence of sets of activities (2). At the same time, the definition of measures for implementation at the next moment in real time $T_{(\tau+\delta)}$ depends on the conditions that were met as a result of the implementation of the measures T_τ at the previous moment in time, as well as on the current state of the decision-making object and the influence of the environment on it.

Obviously, tasks ξ_3 should be solved on the basis of tasks ξ_2 solutions and correspond to frames at the decision-making and implementation levels of the generalized ES model.

Thus, the tasks ξ_3 correspond to the formulation (3) - (8), where the initial data η, $P_\eta^{(n)}$, $P_\eta^{(M)}$, $\{R_{s\eta}\}, s \in S_\eta$, $\{\hat{R}_{q\eta}, \tau_{q\eta}\}, q \in Q_\eta$ are defined as the solution of the tasks ξ_2.

Tasks ξ_2 can be viewed as a special case of tasks ξ_3. It should be noted that the sequence (2) is determined in tasks ξ_3 based on decision making in real time under conditions of incomplete information. The information necessary for solving decision-making problems in ES conditions is updated in real time on the interval Δ_η.

An important feature of the task ξ_3 is that the definition of a set of decisions (activities) T_τ can be carried out on the basis of large amounts of information (knowledge) in the composition and at time moments τ that depend on the current state of the automation object and therefore are unknown in advance.

Thus, the tasks ξ_3 represent by their nature a new class of control problems and can be considered as a generalization of the problems of multistage stochastic control [9].

An analytical solution to the task ξ_3 is obviously impossible, therefore, in [9-11], principles are formulated that make it possible to create practical means of making effective decisions for the implementation of the type of tasks under consideration: the feedback principle provides for an assessment of the current state $\{P_\tau, T_\tau\}$ of the automation object in real time $\tau \in \Delta_\eta$, as a result of the implementation of decisions (measures) $\{T_\delta\} \delta < \tau, \delta \in \Delta_\eta$, which allows to effectively clarify information about the current state of the object; the principle of maximum parallelization of measures (operations) to overcome ES – provides for the need at each current moment of time $\tau \in \Delta_\eta$ to perform all activities T_τ, for which the corresponding conditions P_τ are satisfied, including resource preparation activities $\{\hat{R}_{q\eta}\}, q \in Q_\eta$, the implementation of this principle makes it possible to minimize the time spent on overcoming the consequences of ES; the principle of simulation modeling of management processes based on a knowledge base in real time, which provides, using knowledge-based inference, the formation of the most effective solutions to overcome ES through the use of large amounts of information accumulated in the knowledge base (KB); the principle of optimization of alternative sequences of decisions (measures) based on the coefficients of confidence and reliability, the implementation of which makes it possible to find and implement the best way to overcome ES for a given criterion and volumes of knowledge in KB; principle of event optimization T_τ, $\tau \in \Delta_\eta$ to overcome ES, provides for their most effective implementation, taking into account current information about disturbing influences from the environment and the state of the decision-making object.

The outlined principles allow solving problem (3) - (8) by creating and implementing an intelligent integrated decision support system IIDSS. At the same time, the developed system allows: to use the possibilities of feedback in conditions of incomplete a priori information; to implement the capabilities of simulation in real time to overcome the consequences of ES; use the advantages of expert systems in terms of accumulation and generalization of information, including intuitive ideas of experts by using fuzzy sets and confidence coefficients; optimize the use of large amounts of information in order to improve the efficiency of decisions to overcome the consequences of ES by choosing the most rational of the alternative sequences (9) of decisions (measures).

The above results provide the basis for the development of decision support algorithms in order to overcome the consequences of ES based on solving problem (3) - (8).

The emergence and development of ES is determined by numerous conditions and factors, therefore, to assess the decisions made and the corresponding measures, the future consequences of the implementation of these measures, it is necessary to use modeling of both the ES development processes and the decision-making processes to overcome it. Modeling tools make it possible to determine, for a given initial situation $P^{(n)}$, the most effective strategies for achieving the control goal $P^{(M)}$ according to the set criteria.

The variety of processes that occur when ES occurs at industrial infrastructure facilities necessitates the use of different types of models and modeling methods: analytical models; simulation modeling; graph models, in particular network models, such as Petri nets; physical models, in particular analog computing devices; full-scale models in the form of working models and the like [11].

The main requirement for the quality of the ES modeling process is the integration of the methods and models used in order to comprehensively assess the consequences of the decisions made and the development of ES in the future. Such assessments create the basis for choosing the best alternative solution and optimizing management processes. The basis for the integration of various models, processes in ES, can be the mathematical apparatus proposed in [11].

The modeling process based on this apparatus has the form of a sequence of pairs

$$\{P^M_\tau, T^M_\tau\}, \tau \in \Delta_{\eta M}, \qquad (11)$$

where $\Delta_{\eta M}$ – the model time interval on which the modeling problem is considered;

T^M_τ – operations (measures) recommended as a result of modeling or software tools for implementing models that should be launched at the time $\tau \in \Delta_{\eta M}$ immediately after a set of conditions P^M_τ is met.

The results of modeling processes by means T^M_τ are considered in the form of a new set of conditions $P_{\tau+\delta_r}$, where $\tau+\delta_r$ is the moment of the end of the modeling processes using the r-th model launched at the moment τ.

Thus, (11) can be viewed as an integrated model that combines modeling processes using inference based on production KB and various methods and models that describe processes in ES.

An important feature of the integrated model (11) is the modeling of decision-making processes and their implementation, technological processes in control objects, as well as the influence on these processes from the environment. In this regard, it is advisable to write the integrated model (11) at each moment in the form of a model of decision-making processes $\tau \in \Delta_{\eta M}$ it is advisable to write down in the form of a model of decision-making processes:

$$\{P^M_\tau, T^{MP}_\tau\}, \tau \in \Delta_{\eta M}, \qquad (12)$$

- process models in the automation object:

$$\{P^M_\tau, T^{MO}_\tau\}, \tau \in \Delta_{\eta M}, \qquad (13)$$

- models of environmental influence processes in the form of a sequence of conditions:

$$\{P^{MC}_\tau\}, \tau \in \Delta_{\eta M}. \qquad (14)$$

The relationship between models (11) and models (12) - (14) can be described by the relations:

$$P^M_\tau = P^{MO}_\tau \cup P^{MC}_\tau, \tau \in \Delta_{\eta M} \qquad (15)$$

$$T^M_\tau = T^{MP}_\tau \cup T^{MO}_\tau, \tau \in \Delta_{\eta M}, \qquad (16)$$

where P^{MO}_τ is the set of conditions fulfilled at the moment τ. that describe the current state of the control object;

P^{MC}_τ – is a set of conditions fulfilled at the moment that describe the current influence of the environment;

T^{MP}_τ – a set of operations (activities) that influence P^{MO}_τ and correspond to the decisions made at the moment τ using a decision support system (based on intelligent or analytical methods);

T^{MO}_τ – a set of operations (activities) or tools for modeling processes in an object that are launched at the moment $\tau \in \Delta_{\eta M}$ and affect P^{MO}_τ.

The described methodology for modeling processes related to ES, in addition to the above advantages, together with a generalized model (12), allows the use of a variety of modeling and decision-making approaches, taking into account large amounts of information in order to increase the efficiency of decisions.

The task of modeling ES-related processes, in accordance with the above goal, is aimed at identifying trends in the development of ES and assessing the future consequences of decisions made. Based on the above methodology, the initial data for modeling ES-related processes should be:

- a set of conditions $P^{M(\Pi)}_\tau$, which are performed in the initial situation;
- time interval $\Delta_{\eta M}$, where the modeling problem is considered;
- a set of conditions ρ^{MO}, which describe the possible current state of the automation (control) object during the simulation interval $\Delta_{\eta M}$, that is for each of the sequences possible in the simulation $\rho^{MO}_\tau, \tau \in \Delta_{\eta M}$ there is a ratio

$$\left(\bigcup_{\tau \in \Delta_{\eta M}} P^{MO}_{\eta\tau} \right) \subseteq \rho^{MO}; \qquad (17)$$

- a set of conditions $P^{M(M)}_\eta$, the implementation of which determines the purpose of control in ES;
- set of production rules (18) that represent the content of the KB:

$$P_{qu \to} \{t^M_{u\delta}, P^*_u\}; \qquad (18)$$

where P_{qu} is a set of antecedent conditions, the fulfillment of which is necessary and sufficient for the implementation of measures or launching models $t^M_{u\delta} \in T^{MP}_\delta$, which ensures, after their completion, the fulfillment of many conditions $P^*_u, P_{qu} \subset \rho^{MO}, P^*_u \subset \rho^{MO}$;

- a set T of activities (operations) to overcome ES or models that can be implemented as part of the product rules (18),

$$T = \{T^{MP}_\delta\}, \delta \in \Delta_{\eta M}. \qquad (19)$$

- all the sets of conditions (14) that are specified (predictable) on the modeling interval $\Delta_{\eta M}$ in order to take into account the environmental impact on the processes of overcoming ES;

- a criterion for evaluating ES overcoming processes, which determines the numerical assessment of each of the decision sequences (2) at the interval $\Delta_{\eta M}$ obtained from the simulation.

Based on these data, the integrated model (12) - (14) can be implemented on a computer using a variety of modeling methods that allow the application of production rules (18).

In modeling, decision-making processes are presented in the form of sequences (12), formed on the basis of logical inference and production rules of the form (18) in KB.

The controlled processes in the automation object are presented in the form of sequences (3), which are also formed using logical inference and KB, as well as using other models. The formation of controlled processes (13) occurs under the influence of a sequence of decisions made (12) and models of influence from the environment (14).

The main task of modeling ES that arose as a result of an accident at an industrial facility and accompanied by the release of TCH into the atmosphere is to determine the concentration of TCH as a function of the parameters of the accident, the coordinates of a point in the area, the time elapsed after the accident, and to construct the corresponding concentration fields. The concentration of TCH in the atmosphere can be calculated based on known methods; however, the results obtained are usually of low accuracy, since the general methods are focused on the ideal conditions for the occurrence of accidents. In the calculations, tabular data and calculation formulas are used. To visualize ES development processes, the MATLAB software environment is usually used [12]. When forming the zone where the maximum permissible concentration is exceeded, the direction and strength of the wind, as well as the direction of movement of heat fluxes in the atmosphere, must be taken into account.

In practice, the use of such calculations leads to results with significant errors. The reasons for this are the presence of buildings and structures, woodlands and the like on the path of the TCH cloud. Earlier it was proposed to use elements of the theory of fuzzy sets and expert opinions to determine concentration as a function of coordinates and time.

The standard model for determining the concentration of TCH in the atmosphere is ANFIS, in conjunction with the method of its parametric identification Evomax [6]. In addition to the indicated modeling tools, the dynamics of the development of ES of this type can be reflected using the Toxi-3 methodology [7]. At the same time, the mentioned modeling tools should be supplemented with artificial intelligence and knowledge engineering tools, in order to adequately represent such aspects of ES existence as verification of TCH concentration values in a built-up area or changing terrain, as well as unstable weather conditions.

Thus, the above models and methods should constitute a single technology that allows for end-to-end information and analytical support of decision-making processes, as well as a phased reduction in the level of uncertainty in the process of forming decisions.

The environment for the formation of adequate decisions is the knowledge base, some elements of which are shown in fig. 1. In addition to geographic information data, legislative information, tabular and retrospective data, it contains information about the features of logistics, as well as inference rules presented in the form of production rules. The latter make it possible to use a bank of mathematical models and methods both for structural and parametric identification of a model of a decision-making object under ES conditions. The interactive nature of the functioning of the IIDSS is a prerequisite for the openness of such a knowledge base, since new information about accidents, new models and methods for overcoming ES should be used to replenish and expand the knowledge base and be used in the future as an integral part of it.

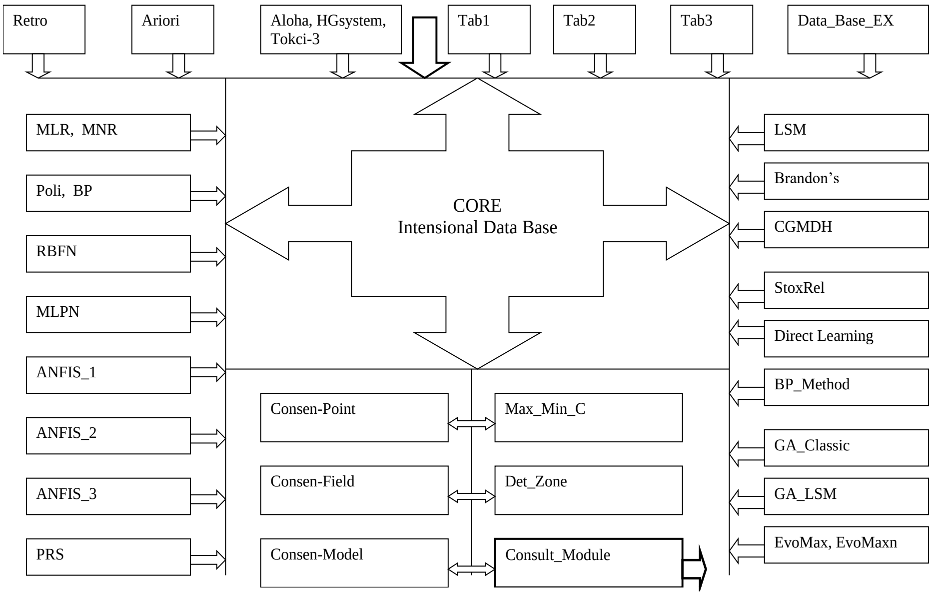

Fig. 1. Functional diagram of IIDSS in ES technogenic conditions

It is advisable to synchronize the operation of IIDSS with one of the geographic information systems. The main part of the knowledge base is a bank of mathematical models and methods, which contains regression, polynomial, Gaussian and diffuse models used in modern techniques, as well as methods for their identification. For each decision-making object, the corresponding knowledge base should be constantly updated with data on the features of production processes and expert opinions. When working with experts with different levels of competence, a model should be provided for determining their competence based on standard methods. Such a multidimensional integration of technologies will allow for a deep analysis of ES, and adequate forecasting of its development.

Consider the content shown in fig. 1, modules. In the upper part of the diagram, modules for entering and storing information in databases and KB are presented, in particular:

- Retro - designed to enter and store data about the existing use cases in the following format:

$$< Id,\ Data\_Id, P_1, P_2, ..., P_i, ..., P_n, x, y, z, t, C >,$$

where Id is the identifier of the accident, $Data\_Id$ - accident data (text file), P_i – initial parameters of the accident, x, y, z – coordinates of the accident point at which the TCH concentration C was measured at the time t;

- Apriori - serves to enter, store and modify data about the enterprise, the place of production and storage of TCH and the routes of its transportation in the form

$$< Id\_P,\ Tip,\ N,\ < Data,\ Id\_i,\ V,\ m >,\ L,\ Data\_P,\ < x_1, y_1, x_2, y_2, ..., x_p, y_p >>,$$

where Id_P – decision object identifier, Tip – type of TCH, N – number of places for production or storage of TCH, $Data$ – date identifier Id_i – identifier of places for production or storage of TCH, V – TCH volume, m – TCH mass, L – number of TCH transportation routes, $Data\_P$ – transportation date, (x_i, y_i) – fiducial points of TCH transport route;

- ALOHA, Toxi-3, HgSystem - modules that are designed to perform calculations for various possible options for a chemical accident and store information in a database of the type

$$< Id\_A,\ P_1, P_2, ..., P_n, x_1, y_1, C_1, x_2, y_2, C_2, ..., x_p, y_p, C_p, Tip >,$$

where Id_A – accident identifier. Obviously, the modules under consideration use information that is generated by the Retro and Apriori modules in the corresponding databases,

- Tab1 – a module for input and storage of information about the parameters of the accident and the TCH concentration, coming from the previous module. The information is presented in the form of a tuple

$$< Id, Id\_E, x_0, y_0, z_0, t_0, Tip >, W_n, W_s, x, y, z, t, C,$$

where W_n – wind direction, W_s – wind speed,

- Tab2 – module for entering and storing information that has a fuzzy presentation,

- Tab3 – module for entering and storing information received from experts with different levels of competence.

To obtain a model of TCH concentration in the post-accident period, the initial data are the results of analytical calculations, taking into account various expert adjustments, tolerances and assumptions.

As an example, a conditional scenario of ES occurrence due to the spread of TCH in the atmosphere, as a result of damage to a container with a hazardous chemical substance, has been developed: the emission volume is 2000 m3 or the volumetric emission velocity of 4.3 m3/s; the proportion of TCH in the gas mixture is 31%; wind speed 2.1 m/s; the duration of the ejection is about 400 s. The initial data table has the form (table 1).

Table 1. *Initial data on ES (fragment)*

No.	Wind speed, m	Wind direction, deg.	Air temperature, °C	TCH mass, kg	Hole diameter, m	Opening height, m	x_0	y_0	t_0	x	y	t	C
1	1	45	25	7,46	10	10	0	30	5	2130	1230	44	30
2	2	60	-10	12,4	5	6	20	30	5	8360	980	50	0,75
…	…	…	…	…	…	…	…	…	…	…	…	…	…
20	4	25	12	69,2	15	3	20	30	5	8760	2720	17	0,02

In the event of ES caused by the propagation of TCH in the atmosphere, it is enough to supply the values of the corresponding parameters to the model input and obtain the value of the TCH concentration at any point in the TCH propagation region.

In fig. 2 shows the shapes of the surfaces indicating the boundaries of the region in which the maximum allowable concentration of TCH is exceeded at the fifth and three hundredth seconds of ES existence.

To determine the effectiveness of the developed technology, a comparative analysis of the efficiency of calculating ES characteristics using various models and techniques was carried out [13-15]. The results of the analysis are shown in table. 2.

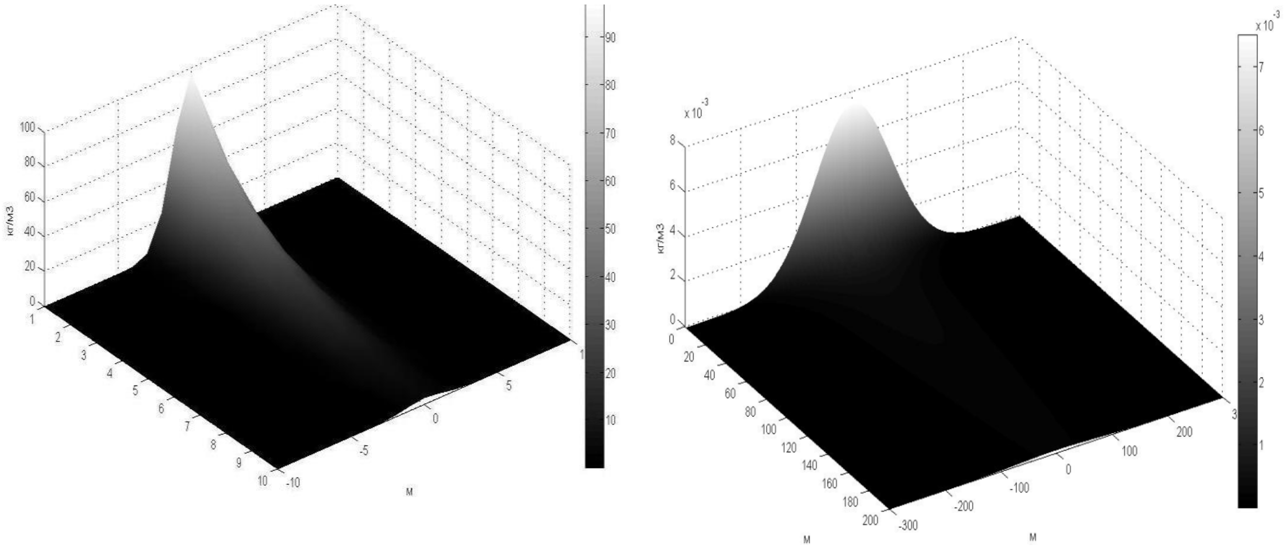

Fig. 2. Concentration of TCH in the atmosphere 5 and 300 seconds after the release of TCH at the decision-making facility

Table 2. *Simulation results*

Concentration,%							Calculations time			
EvoMax	**Avg**	**Gaussian model**	**Toxi-3**	**Rbf-net**	**ANFIS+ EvoMax**	**ANFIS+ modif. EvoMax**	**RBF-net**	**ANFIS+ EvoMax**	**ANFIS+ modif.. EvoMax**	**ANFIS**
12	9,5	42	13	10	9,8	9,71	12	44	36	134
9	8	14	7,8	9,3	7,7	8,04				
1	0,6	4,5	0,85	0,95	0,62	0,59				

The dependencies presented in fig. 3 show that the use of the Evomaxm method during the functioning of IIDSS yielded forecast values with an average relative deviation of 2.2–6.3%, which indicates a significant superiority of this method over the rest in predicting the ES characteristics associated with the spread of TCH in the atmosphere.

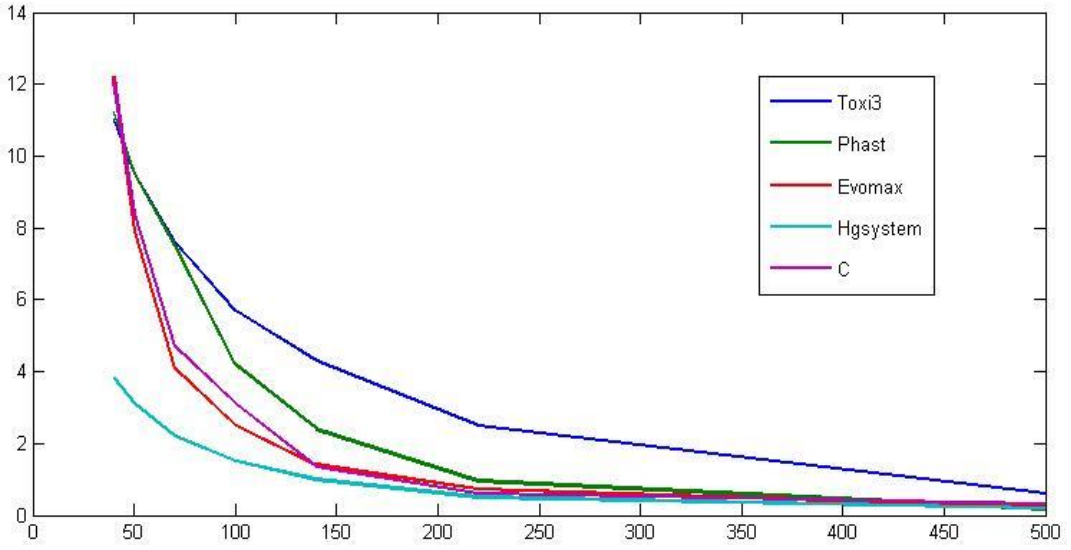

Fig. 3. Prediction of TCH concentration by different methods

The accuracy of solving a set of tasks to overcome ES that arose as a result of chemical accidents is a prerequisite for carrying out measures to save people, minimize material damage and prevent environmental disasters.

Conclusions

The above description of a typical ES-related process modeling task allows to take advantage of the above mentioned advantages of the proposed concept and creates a methodological basis for the development of, and software tools for process modeling in specific applications.

1. The formal setting of the typical decision-making task in ES is described as the task of optimizing management according to the given criteria in conditions of incomplete information taking into account resource restrictions, as well as the basic principles of its solution are described.

2. Developed the task of modeling the management processes associated with ES of a technogenic nature, as well as the methodology of its solution based on the integration of logical inference methods using the knowledge base and various models that describe processes in ES of a technogenic nature.

3. Using a scenario example, the features of the functioning of IIDSS in determining the scale and response to chemical accidents were analyzed.

Further research will complement the concept with approaches to knowledge acquisition and explanation generated during system operation.

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КОНЦЕПЦІЯ СТВОРЕННЯ ІНТЕЛЕКТУАЛЬНОГО ЯДРА ІНТЕГРОВАНОЇ ІНФОРМАЦІЙНО-АНАЛІТИЧНОЇ СИСТЕМИ ЩОДО ДІЙ У НАДЗВИЧАЙНИХ СИТУАЦІЯХ ТЕХНОГЕННОГО ХАРАКТЕРУ

Предмет. Інформатизація процесів протидії надзвичайним ситуаціям техногенного характеру. **Мета.** Підвищення ефективності процесу інформаційної підтримки прийняття рішень при подоланні наслідків техногенних надзвичайних ситуацій, в аспекті її інтелектуалізації, шляхом створення концепції інтеграції різноманітних програмних засобів в рамках єдиного, гомогенного простору знань про стратегічні, тактичні й оперативні дії в умовах широкого спектру аварій та катастроф, пов’язаних із функціонуванням технічних об’єктів. **Завдання.** Розробити формальну постановку задачі прийняття рішень в умовах надзвичайної ситуації та обґрунтувати методологію її реалізації на основі інтеграції засобів виведення на знаннях із різноманітними аналітичними моделями, що описують процеси існування надзвичайних ситуацій. Розглянути застосування запропонованої методології на сценарному прикладі, що відтворює ситуацію на об’єкті після витоку сильно діючої отруйної речовини. **Методи.** Системний аналіз – при розробці комплексної процесної моделі прийняття рішень в умовах надзвичайної ситуації; програмна інженерія – при створенні архітектури інтегрованої інтелектуальної системи підтримки прийняття рішень в умовах надзвичайних ситуацій техногенного характеру; фізика процесів розповсюдження отруйних хімічних речовин в атмосфері – при розробці сценарного прикладу обстановки на об’єкті в умовах надзвичайної ситуації на промисловому об’єкті. **Результати.** Концепція створення інтегрованої інтелектуальної системи підтримки прийняття рішень щодо подолання наслідків надзвичайних ситуацій техногенного характеру, зокрема, описано формальну постановку типового завдання прийняття рішень у НС, а також викладено основні засади її вирішення, та розроблено постановку завдання моделювання процесів управління, пов'язаних із НС техногенного характеру. **Висновки.** Викладено концепцію створення інтегрованої інформаційно-аналітичної системи підтримки прийняття рішень в умовах техногенних надзвичайних ситуацій. В рамках даної концепції розроблено формальні моделі прийняття рішень в умовах техногенних надзвичайних ситуацій та підхід до інтеграції різнорідних програмних засобів в рамках єдиного, гомогенного простору знань про комплексні заходи щодо подолання наслідків надзвичайних ситуацій, що пов’язані із аваріями та катастрофами на об’єктах технічної інфраструктури. Розглянуто сценарний приклад організації інтелектуальної підтримки рішень при викиді в атмосферу отруйної хімічної речовини.

Ключові слова: надзвичайна ситуація техногенного характеру; підтримка прийняття рішень; процесна модель; інтегрована інтелектуальна інформаційно-аналітична система; отруйна хімічна речовина.

КОНЦЕПЦИЯ СОЗДАНИЯ ИНТЕЛЛЕКТУАЛЬНОГО ЯДРА ИНТЕГРИРОВАННОЙ ИНФОРМАЦИОННО-АНАЛИТИЧЕСКОЙ СИСТЕМЫ ПО ДЕЙСТВИЯМ В ЧРЕЗВЫЧАЙНЫХ СИТУАЦИЯХ ТЕХНОГЕННОГО ХАРАКТЕРА

Предмет. Информатизация действий противодействия чрезвычайным ситуациям техногенного характера. **Цель.** Повышение эффективности процесса информационной поддержки принятия решений при преодолении последствий техногенных чрезвычайных ситуаций, в аспекте ее интеллектуализации, путем создания концепции интеграции разнообразных программных средств в рамках единого, гомогенного пространства знаний о стратегических, тактических и оперативных действиях в условиях широкого спектра аварий и катастроф, связанных с функционированием технических объектов. **Задание.** Разработать формальную постановку задачи принятия решений в условиях чрезвычайной ситуации и обосновать методологию ее реализации на основе интеграции средств вывода на знаниях с аналитическими моделями, описывающими процессы существования чрезвычайных ситуаций. Рассмотреть применение предлагаемой методологии на сценарном примере, воспроизводящем ситуацию на объекте после утечки сильно действующего ядовитого вещества. **Методы.** Системный анализ – при разработке комплексной процессной модели принятия решений в условиях чрезвычайной ситуации; программная инженерия – при создании архитектуры встроенной интеллектуальной системы поддержки принятия решений в условиях чрезвычайных ситуаций техногенного характера; физика процессов распространения ядовитых химических веществ в атмосфере при разработке сценарного примера обстановки на объекте в условиях чрезвычайной ситуации на промышленном объекте. **Результаты.** Концепция создания интегрированной интеллектуальной системы поддержки принятия решений по преодолению последствий чрезвычайных ситуаций техногенного характера, в частности, описана формальная постановка типовой задачи принятия решений в ЧС, а также изложены основные принципы ее решения, и разработана постановка задачи моделирования процессов управления, связанных с ЧС техногенного характера. **Выводы.** Изложена концепция создания интегрированной информационно-аналитической системы поддержки принятия решений в условиях техногенных чрезвычайных ситуаций. В рамках данной концепции разработаны формальные модели принятия решений в условиях техногенных чрезвычайных ситуаций и подход к интеграции разнородных программных средств в рамках единого, гомогенного пространства знаний о комплексных мерах по преодолению последствий чрезвычайных ситуаций, связанных с авариями и катастрофами на объектах технической инфраструктуры. Рассмотрен сценарный пример организации интеллектуальной поддержки решений при выбросе в атмосферу ядовитого химического вещества.

Ключевые слова: чрезвычайная ситуация техногенного характера; поддержка принятия решений; процессная модель; интегрированная интеллектуальная информационно-аналитическая система; ядовитое химическое вещество.

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