UDC 004.9:519.2

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Information Technologies of Decision Support in Transboundary Emergencies

The transboundary character of any emergency leads to the additional challenges, namely, the absence of the direct access to center of accident and possible difficulties in the relationship with the authorities of the neighboring territory. The given work represents the information technology that allows to deploy the emergency infrastructure in the shortest terms, collect and process environmental data from different data sources and transfer it to the decision support system in a real-time mode, thus, improving the efficiency of decision-making process.

Introduction.

The transboundary environmental monitoring is a complex process that involves many parties that can represent different regional or state authorities and services. One of the most difficult sides of this activity is organization of efficient interaction between all parties. Environmental data collection from various sources and its fusion under a single control system is not a simple task in itself. This task becomes even more complicated when it has to be completed on the transboundary territories. The situation when the authorities separated by the administrative boarder don’t cooperate properly is not a rare case in the modern world. The examples include hostile relations between neighboring countries/regions, political conflicts, armed conflicts, territories occupation and wars. For instance, after the chemical weapon attacks in Syria in April 2018, the authorities of the neighboring territories did not have an access to the emergency epicenter, thus, couldn’t collect the information on the hazardous substances and react properly and timely. Currently, Ukraine with its occupied territories faces the similar problems as well. For example, the chemical emission on the plant in Armiansk (the territory of the Crimea) in August 2018 had its outcomes in the neighboring Ukrainian territories. In this case, the work of Ukrainian rescue services was embarrassed much by the impossibility to collect the data on environmental indicators directly in the center of emission and the need to analyze the incomplete data from transboundary territories only. This negative experience makes it obvious that transboundary emergencies require additional efforts to localize and eliminate their outcomes.

The tasks of decision making in the case of emergencies are differed substantially depending on the operation mode of the automation object to which these tasks relate. It is reasonable to distinguish three types of tasks:

- tasks to prevent emergencies that are solved in regular modes of operation before the emergency situation occurs (the regime of mitigation);
- tasks of immediate response to the emergency situation;
- problems of overcoming the consequences of emergency situations.

The tasks of the first type include the formation of resources and the implementation of activities that reduce the probability of emergencies. Solving such problems requires preliminary material costs. The increase in these costs leads to a reduction in the probability of emergencies, so these tasks are actually tasks of risk management.

The tasks of emergency situation identification, selection, and implementation of protective measures belong to tasks of the second type. These tasks should be done immediately using available resources, as well as identifying the necessary additional resources to prevent development and to overcome the consequences of emergencies.

The third type of tasks covers the tasks of defining and realizing in real time the set of activities and operations that are most expedient for overcoming the consequences of emergency situations.

The aim of the research is to build the information technology of decision support based on multisource data processing and process modeling.

Problem statement.

The process of transboundary emergency [1] containment implies the cooperation of multiple rescue services that are coordinated by the main command center. The basic function of this command center is the collection of information from various services, its analysis and decision making. To improve the decision-making process in emergencies, it is suggested to use the information technology that provides the efficient gathering of data from multiple sources, its delivery to the command center, analysis and decision support. The suggested solution allows deploying a decision support system in the case of emergency, merge the data from different rescue services and based on a complete information react in a timely manner.

The most challenging aspect of environmental monitoring [2] under the conditions of transboundary emergency is collection of data from a big number of devices and sensors controlled by different rescue services in the real-time mode and its transmission to the decision-making system. Rescue services use devices of different types that measure various indicators. For example, remotely piloted vehicles of different manufacturers are used to measure the content of harmful substances in the air. This data obtained from multiple devices has to be integrated into a single decision support system controlled by the emergency command center [3]. This hierarchy of data sources, devices, their control units and a central command unit lead to the idea to use the service-oriented architecture of the emergency infrastructure deployment.

The main idea is that in order to support decision-making, it is necessary to be able to connect any number of devices to the decision support system in the real-time manner. For this purpose, we suggest to develop a data fusion and pre-processing layer which is a middleware between devices and decision-support system.

Results.

The current state of objects in an emergency situation can be formally represented in the form of a set of fulfilled conditions P_τ and a set of activities (control actions) T_τ, that are executed at the moment τ of real time.

Using the designations introduced the processes of managing the object in an emergency situation on the time Δ_η interval can be written in the form:

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

where $P_\eta^{(n)}$ - a set of conditions fulfilled at the initial moment of the emergency situation occur $\tau_0, \tau_0 \notin \Delta_\eta$;

P_τ, T_τ- the set of fulfilled conditions, and the set of measures (operations) that are performed at the current time τ;

$P_\eta^{(M)}$ - set of conditions defining the purpose of management in an emergency situation, the fulfillment of these conditions ensures the overcoming of the consequences of an emergency situation;

η - an index of the specific implementation of management processes in an emergency situation that has arisen for a given automation object in specific environmental conditions.

In actual cases occurrence of emergency situations must be determined by equation (1) based on the object monitoring data. Therefore, equation (2) defines a certain problem of the second type, can be written as follows:

$$P_{\tau_0} = P_\eta^{(n)}, \eta \in H \qquad (2)$$

where τ_0 is the moment of occurrence of an emergency situation, which is determined by the set of fulfilled conditions $P_\eta^{(n)}$.

Obviously, the index $P_\eta^{(n)}$ in (2) can be considered as the identifier of a specific emergency. Then H is the set of types of emergencies.

Thus, the problem of combating emergencies can be written down in the form of three types of tasks:

- emergency prevention tasks ξ_1;
- immediate response tasks at the time of emergency ξ_2;
- tasks to overcome emergency situations ξ_3.

The tasks ξ_1 are related to the planning of emergency prevention measures and are qualitatively different from the decision-making tasks directly in emergency situations.

The tasks ξ_2 include:

- timely detection of emergency situations on the basis of equation (2);
- identification of emergency situations, i.e. determining the type of emergency using equation;
- the goal identification of overcoming emergency situations in the form of a set $P_\eta^{(M)}$;
- 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 emergencies, as well as to prepare the necessary resources$R_s, s \in S_\eta$.

The tasks ξ_3 include the search and the implementation of a set of measures (1) that are best for the given initial situation $P_\eta^{(n)}$ and the criterion of effectiveness in a given emergency situation, taking into account the resource constraints that ensure the achievement of the target situation $P_\eta^{(M)}$.

The tasks ξ_2 are characterized by a one-time decision-making. The tasks of this group are solved first by constantly monitoring the current state of objects by the time the emergency situation is identified (using equation (2)). After that, the process of solving problems is transferred to the decision-making frame in the relevant emergency situation. With the help of the content of slots and associated procedures of this frame, the target management situation in the form of sets of conditions, available resources are defined. Also, a list of urgent measures for protection, prevention of emergencies development and preparation of necessary resources are determined, as well as an implementation of these activities.

The tasks ξ_3 for their solution require the specification and implementation of a real-time set of activities. At the same time, the determination of measures in the next moment depends on the conditions that were met as a result of the implementation of measures, at the previous point in time, as well as on the current state of the facility and the environmental impact.

These tasks should be solved at the decision-making levels and implement the activities of the generalized typical emergency model. The analytical solution of the problem is obviously impossible; therefore, principles must be formulated that allow us to create practical tools for making effective decisions to solve this problem:

The principle of feedback involves assessing the current state of the automation object at the moment of real time.

The principle of maximum parallelization of measures to overcome emergency situations requires the need for each current time to perform all activities for which the relevant conditions are met.

The principle of simulation modeling provides the formation of the most effective solutions for overcoming emergencies due to the use of large amount of information accumulated in the intellectual core.

The principle of alternative sequences optimization (1) is based on confidence and reliability coefficients. The implementation of this principle allows us to find and implement the best way to overcome the emergency situation for a given criterion and the amount of knowledge.

The principle of operation optimization provides for the most effective overcoming of emergency situations, taking into account current information about the disturbing influence of the environment and the state of the facilities.

Conclusion.

Different rescue services that participate in the emergency management provide the heterogeneous data that may be duplicate, inaccurate, incomplete and unreliable. To merge this data obtained from various sensors and devices, in particular, remotely piloted aircrafts, we suggest the data fusion technology based on the implementation of the device meta-model. This model implements interfaces and protocols that allow integrating any new device into the currently deployed emergency infrastructure in the real-time mode and start getting data from it immediately.

The above principles make it possible to solve problem by creation and implementation of an intelligent integrated decision support system.

By using these principles, the decision-making system has the following capabilities:

- the use of feedback in the conditions of incomplete a priori information;
- realization of simulation modeling of processes in real time of emergency;
- using the advantages of expert systems in terms of accumulation and generalization of information, including intuitive views of experts through the use of fuzzy sets and confidence coefficients;

-rational use of large amounts of information to improve the effectiveness of solutions to overcome the consequences of an emergency by selecting the most possible of alternative sequences (2) solutions (activities).

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