Applications of Analytical Technologies in Safety Management of Territories*

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Abstract. The methods of analytical data processing used for support information tasks for managing the security of territories are considered. The problem of data availability for operating analytics is investigated. The use of end-to-end decision-making support technologies in different territorial management tasks is shown. Identification of environmental and anthroposphere parameters by using the developed regulatory values is the basis for early response to hazards. Risk assessment using comprehensive data analysis is used to justify priority measures to improve the safety of the territories. The use of OLAP, Data Mining, Machine Learning to jointly processing Big Data of monitoring, hazard event catalogs and territory features allows quickly and effectively preventing threats to people life.

Keywords: Data Preprocessing, Threat Identification, Assessment of Territorial Risks, Safety Management.

1 Introduction

The growing number and scale of various danger manifestations, accumulation of large amounts of data, and development of intelligent information processing technologies necessitate the search for new methods to support the management of natural and technogenic territorial security. The use of analytical tools makes it possible to effectively solve complex and multifaceted problems of managing the integrated territorial security, to predict emergency situations (ES) of particular types. Sufficiently good scientific elaboration of analytical methods for assessing the territory characteristics as complex systems is often poorly implemented in practice. The main reason is the scarcity or inaccessibility of structured data. The data analysis methods used nowadays allow obtaining generalized background safety assessments [1]. Such assessments are not enough for making decisions on reducing risks in taking protective measures. Differences in the initial data used to compare different territories lead to the need to apply correction factors that reduce the credibility of estimates. The approaches based on the extreme statistics methods for processing catalogs of emergencies and other dangerous events have not found wide practical application [2]. It requires the development, standardization and replication of integrated analytical models which allow studying territories on different scales (from a country to a separate municipality).

The paper presents a brief description of the developed approaches and promising directions for solving management problems using analytical technologies.

The paper is organized as follows. Section 2 reviews features of data preprocessing. Section 3 presents a description of the on-line analytical processing for integrated monitoring data. Analytical Methods for Assessing the Territorial Risks of Emergencies are discussed in Sect. 4. Finally, the conclusion is given in Section 5.

2 Data Preprocessing

The use of analytical methods in the management of territories, in contrast to that of enterprises and corporations, is in its infancy [3, 4]. The identification of the characteristics of the condition of technosphere objects, environmental parameters, social systems which are significant for analytical processing, including the construction of conceptual models of territories is a difficult task. In addition to determining quantitative indicators characterizing the state of safety at different time intervals, it is necessary to ensure their timely updating. The availability and quality of monitoring data is constantly growing, but a significant part of information resources of corporate systems is closed for researchers.

The studies show that most of the data that ensure solving the problems of prevention and elimination of emergencies in Russia require the development of new approaches to data structuring [5]. This is connected not only with the prospects of using Big Data, neural networks, but also with avoiding the practice of using office systems for collecting, processing, and exchanging information. The existing reporting procedure in the hierarchy of territorial security management has a few problems, including:

- poorly elaborated data structure forces one to collect additional information, often in a time pressure mode;
- large data volumes lead to duplicate data, whose consistency is difficult to verify;
- office data exchange formats do not support the independence of elements, and names of disciplines, contributing to frequent changes in the structure of the collected data;
- lack of services and data collection programs leads to overloading specialists at all levels of territorial management with routine work on the consolidation or transformation of reports;
- integrity of archives is not maintained, which worsens the starting conditions for the application of analytical methods;
- lack of uniform reference books and classifiers complicates the use of analytical technologies, and leads to ambiguous results.

To fill the gaps in the generated arrays of formalized data, a distributed data collection system was developed using the information model [6]. The system provides effective support for all the stages of the information consolidation process, from the tabular form preparation to the provision of collected data. A special toolkit for operational modification of the information model allows one to adapt the system when expanding the subject area, adding tabular forms for information providers. The operation of the system in the territory administrations of the Krasnoyarsk Region for 10 years has made it possible to collect a large array of data on events requiring prompt response of emergency services, and to consolidate information on hazards coming directly from the population. The collected data do not need preprocessing; their primary analysis is performed directly in the system.

The basis for structuring monitoring data is the ontology of the subject area. The methodology for building ontology is described in [7]. The ontology contains a description of the relationship of control tasks, types of dangerous situations, data types, data assessment methods, including centralized and distributed storage.

The advantage of the approach is the co-processing of monitoring data, hazardous event catalogs and territory features. This allows a complete description of the state of security of the territory. Frequently occurring events, such as mining-related calls, mercury spills, etc. are difficult to monitor by usual means. The ontology allows us to determine the structure and content of analytical models at the conceptual level, considering the tasks of management.

An additional source of data is mapping information used both for visualization and modeling. For example, spatial analysis can identify areas of pipelines with an increased risk of accidents based on relief models, or assess the characteristics of rivers, roads, and protective belts as obstacles for the spread of natural fires.

Providing instant access to data is especially important in the event of an emergency when it is required to formulate solutions in the shortest possible time. For example, the automatic location and identification of the phone owner can reduce the critical call time of emergency services. A request for the actual characteristics of buildings in the process of modeling the consequences of an emergency is necessary to clarify the consequences of the impact of hazardous factors on the protected objects and to form groups of forces and means corresponding to the scale of the event.

The full implementation of the structure of information resources described in the ontology requires the creation of standardized API services for monitoring data sources and their meta descriptions. The development of data exchange protocols is relevant, for example, the international standards SDMX and OGC [8, 9]. This will make it possible to provide direct calls to systems within the framework of web services technologies using the XML / SOAP / HTTP protocols, while observing the independence of the hardware and software for the implementation of external systems.

3 On-Line Analytical Processing for Integrated Monitoring Data

One of the simplest but most important analytical tasks is identifying hazards and threats in monitoring data streams. The detection of events related to the parameters of environmental conditions and technosphere objects exceeding the normative values allows one to promptly notify the emergency services and inform the population. A list of parametric and logical criteria for identifying pre-emergency and hazardous states of the controlled objects, processes and systems is proposed in [10]. The OLAP analytical models use the critical values established by the industry regulatory documents, as well as results of a joint analysis of observation archives and data on dangerous events which previously occurred. Hazard and threat identification for the current and forecast data is integrated with the situational modeling technology. This allows describing the consequences of the hazardous situation and making decisions on early warning of the population and the response of emergency services.

The joint analytical processing of the parameters for monitoring hazards and object characteristics in the protected areas allows evaluating the possible consequences of signaling dangers and threats. A comprehensive hazard assessment is implemented using the OLAP technology. For example, abnormal weather events such as extremely low temperatures, squally winds, and prolonged precipitation do not harm infrastructure and facilities located in the Arctic zone but pose a great threat in southern latitudes. Operational estimates of the hazards magnitude with the same parameters can also change, depending on the capabilities of the rescue services. The preliminary ranking of territories according to the risk degree makes it possible to justify different criteria of hazards, depending on the location of the observation point, frequency of the controlled events and other conditions [11].

Information support for management decisions in the conditions of uncertainty is formalized in the form of information processes, including analytical modeling [12]. The main processes of analytical processing using OLAP are implemented in the ESPLA-M information and analytical system. The system is used in the Territorial Center for Emergency Monitoring and Forecasting of the Krasnoyarsk Region for early detection of dangers and threats, and prompt provision of detailed information about the situation. Using the system, a data warehouse for complex operational monitoring of the situation was built, its volume allowing one to solve a few related tasks of control support. This includes the analysis of the natural and man-made emergency risks, formation of analytical reports, etc.

Operational analytical data processing is shown in Figure 1. Hazard identification is carried out in several stages. First, the received data packets from an external source are verified for false signals. Then, the identification of hazards is performed based on a single parameter. The regression analysis allows predicting 3-5 values, and on its basis warnings about threats are made. Analytical modules that process data from different sources work independently. This allows one to customize them for a specific data update schedule (from minutes to days), to match the expected values to the base of text templates of informational messages. Multivariate analysis is used to analyze the types of situations depending on weather, for example, flood dangers, occurrence and development of wildfires, and traffic situation.

A website and a mobile application for displaying the results of the analytical processing, as well as a service for information messages were developed. To improve the information perception, a dynamic mapping technology was developed which illustrates monitoring data in the form of special symbols and explanations for each observation point. Multivariate results are visualized using infographic libraries. The main advantage of the approach is a quick transition from the aggregated characteristics of a situation (danger signals and threats) to individual detailed parameters and their dynamics.

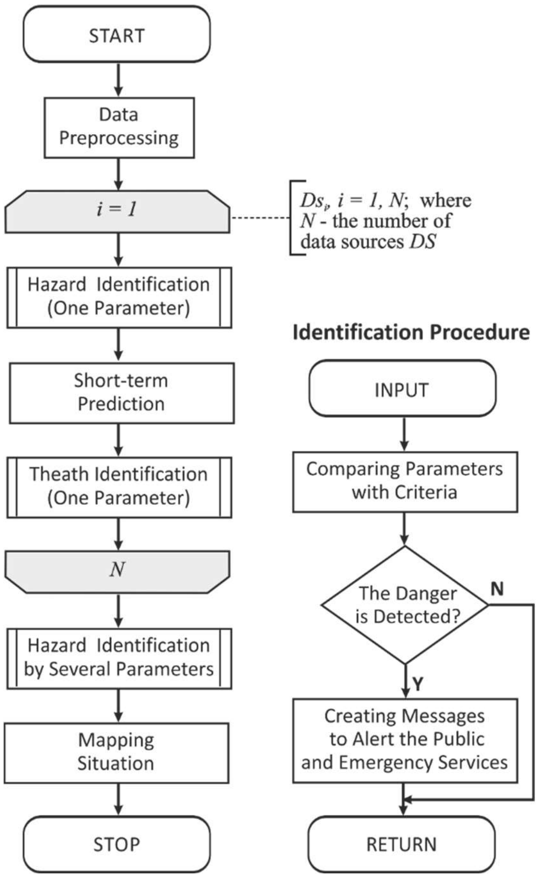

Fig. 1. Analytical processing scheme of operational monitoring data.

The implementation of this analytical processing made it possible to control the environmental parameters throughout the region, as well as those of pilot industrial facilities and communication in industrial centers. The problems identified during the operation which are related to the quality of data and the presentation of the processing results were considered in the projects of the system development for integrated operational emergency situations monitoring.

4 Analytical Methods for Assessing the Territorial Risks and Emergencies

The priority area of using analytical methods is the assessment of territorial risks to justify strategic measures to prevent man-made disasters, mitigate consequences of natural disasters. The early studies of the risk constituents were based mainly on the expert judgment. Such coefficients, considering the peculiarities of territories, situation types, conditions of their occurrence, make it possible to assess the interaction of the system elements of any complexity. This requires the same type of a collection of experts' opinions, which in a real situation is difficult to perform.

Using Big Data of complex monitoring, providing the interdepartmental information exchange solves the problem concerning the lack of information necessary for the risk assessment [13, 14]. Methods were developed for comparing heterogeneous indicators along with assigning the priorities for managing measures to reduce the risks for territories. The methods are based on the systematic analysis of the entire set of risk factors, considering their mutual influences. The factors can be grouped according to the degree of management complexity, and influence on the estimated risk value, taking into account the information sources and other characteristics.

Analytical assessment makes it possible to justify the choice of the location and extent of measures to prevent emergencies and mitigate their consequences. The design of the models is implemented graphically using the Ishikawa cause-effect diagrams. The first level of charts describes the statistics of hazardous events; territory characteristics, including natural, demographic, socio-economic factors; data block for monitoring environmental parameters affecting the likelihood and scale of hazardous events. At the second level, the detailed factors are represented by independent indicators, which allow building analytical data cubes. Assessment of the state of territory security is made by comparing the indicators or calculating the integral values.

5 Conclusion

Using analytical processing technologies in combination with services for the consolidation of complex monitoring data has increased the efficiency of the territorial security management. The efficiency and reliability of the data used for decision-making have qualitatively changed, and the possibilities for informing the population have been expanded. Early warning about dangers and threats allows saving resources by eliminating emergencies at the inception stage, and timely help to casualties reduces losses from accidents.

Decision support implemented using the analytical technologies and big data, provides the possibility for self-learning in the situations that have already occurred [15,16]. Information and analytical systems instantly providing numerous solutions will assist specialists in most areas of management in the foreseeable future [17]. For example, the intellectualization of the call processing in call centers allows virtualizing emergency message reception System 112 (such as 911 in the United States), if used as one of the providers of Big Data. The analytics used at all territory administration levels will allow one not only to reduce losses from emergencies by deeply justifying preventive measures, but also to change the structure of the territorial security system, minimizing the bureaucracy [18, 19].

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