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Cognitive approach in the implementation of local geodynamic monitoring

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Abstract

International practice shows that the most effective way to reduce the socio-economic consequences of natural and man-made emergencies is to prevent them. This prevention is based on constant monitoring of industrial facilities and provides information support for the procedures of decision-making to prevent such emergencies. Far years, higher requirements are placed on systems for monitoring, modeling, forecasting and managing emergencies. One of the possible solutions is the cognitive modeling – an approach based on new opportunities in the field of mathematical modeling, information technologies and telecommunications.

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Keywords: earthquake, seismic activity, geodynamic monitoring, cognitive modeling.

1. Introduction

Seismic monitoring is an integral part of the life support of regions with significant seismic activity and systems for ensuring the safety of critical structures (power plants, wells, mines, bridges, etc.). This monitoring includes not

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only registration, but also further operational processing and interpretation of seismological data to make forecast estimates [1].

According to statistics provided on the website of the US Geological Survey, an average of more than 1,700 earthquakes of magnitude of 5 points and above occur each year. An annual number of earthquake victims ranges from 200 to 300,000 people and economic damage is growing from year to year. According to experts, material damage as a result of natural disasters and man-made disasters reached a record high in history in 2011, exceeding $ 370 billion. About half of that money was spent on the consequences of the tsunami in Japan, which arose as a result of the strongest earthquake in the history of Japan. The accident at the Fukushima-1 has already cost $ 75 billion, and the total cost of eliminating and mitigating the consequences of this disaster over a number of years should exceed $ 250 billion [2].

This situation occurs as a result of:

- the ongoing global climate changes that have accelerated in the last decade;
- the synergistic nature of many disasters starting in one area, they exacerbate or cause processes in another area. The earthquake triggered the tsunami, that led to the accident at the nuclear facility. This chain of events clearly showed the danger of such a synergistic interaction.
- the lack of readiness of international, national, and corporate governance systems to respond quickly, adequately, and effectively to such events.

Prevention of critical situations caused by earthquakes and aftershocks is the issue of the decision support system for monitoring the geodynamic state of the region [3].

2. General characteristics of the developed system

The general concept of the automated system (AS) is to collect raw data from seismic stations, transfer this data to the primary processing station and record the data for long-term storage. Further, after the primary processing, the data can be uploaded for further analysis to teach and train the system to classify the received signals. Next, the decision is taken on what kind of measures are necessary to prevent a critical situation.

The process of operation of the AS can be described as follows: data packets from seismic stations are recorded in hourly files in constant mode. In parallel, the data is converted to a floating-point format and it is visualized in a real time. Further, the ratio of the signal amplitudes in the short and long time periods (STA/LTA - Short Time Average to Long Time Average) is estimated. If the STA/LTA exceeds the specified value, the detected event is classified into critical and non-critical [4].

The AS records the time for a critical event and select a fragment for its analysis. For the selected fragment, AS plots the D-spectrum and its frequencies are compared with the event signature database. The system is sending a warning to a computer about a possible critical event.

Based on this data, geophysicist monitors the current events in the region where the industrial facility is located.

Using the ArchiMate notation, a top-level scheme of this process is developed (Fig. 1).

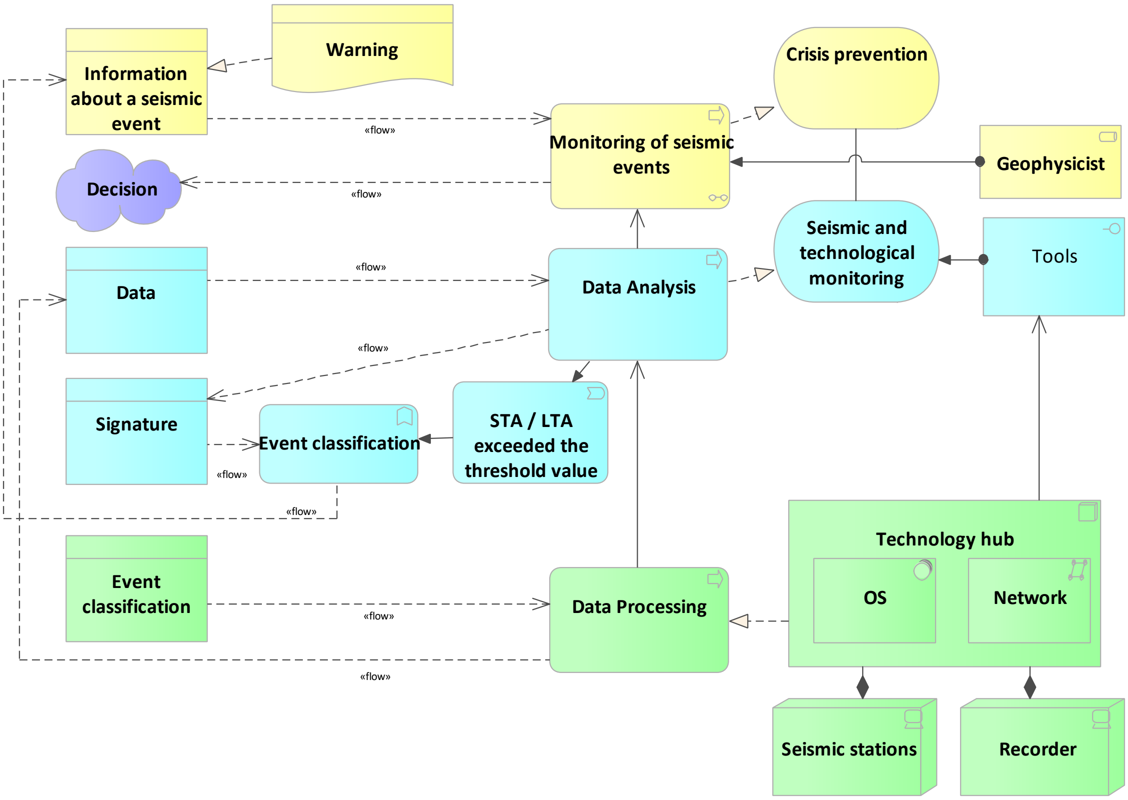

Fig. 1. General description of the AS in ArchiMate notation

The system is designed for geodynamic monitoring of the object location region, dynamic technological loads on buildings and geometric deviations to determine the residual safety margin and other natural or man-made factors [5,6]. Moreover, based on the results of geodynamic monitoring, predictive findings are formed on the level of seismic danger in the region and a control over natural and man-made dynamic loads on the buildings and structures of the object is provided.

In addition to the data received from local seismic stations and technology recorders, there is also a global seismic network, as well as various data channels that can be used to identify critical seismic events and to make decisions in the event of an emergency.

3. Cognitive modeling as a method of analyzing geodynamic monitoring data

Cognitive science is an interdisciplinary field that combines the theory of artificial intelligence, cognitive psychology, cognitive theory, neurophysiology, nonverbal communication, and cognitive linguistics. The intersection of these areas of knowledge is the point of emergence of a new, gaining strength approach of Brain-Inspired Cognitive Architectures for Artificial Intelligence (BICA) [7]. When designing and developing a decision support system, a cognitive approach will allow for the creation of databases in the field of complex systems design.

Weakly structured systems are characterized by the complexity of process analysis in conditions of insufficient quantitative information about the development (dynamics) of processes, as well as changes in the characteristics of these processes and their components. In a multi-factor field, it is extremely difficult to determine the logic of the events that occur. To resolve this problem, it is necessary to use cognitive modeling in the form of developing a cognitive map of the situation.

The construction of a cognitive map implies a scenario approach, i.e. the joint use of trends, existing goals for development, order of actions and activities to achieve goals, as well as factors that characterize further development of the situation.

To build a cognitive model, it is necessary to:

- determine the primary conditions for the development of the situation;
- set goals and directions for changing the situation;
- define a set of activities to achieve the goals;
- determine the factors that characterize further development of the situation.

This approach will allow to investigate the problem, structure and formalize the knowledge obtained at the current stage of modeling, and identify promising areas for the development of situations.

4. Cognitive modeling technology

Cognitive modeling and its technology are dictated by the structuring of knowledge about both the object under study and its outside environment. The diagram below shows the technology of cognitive analysis and modeling (Figure 2).

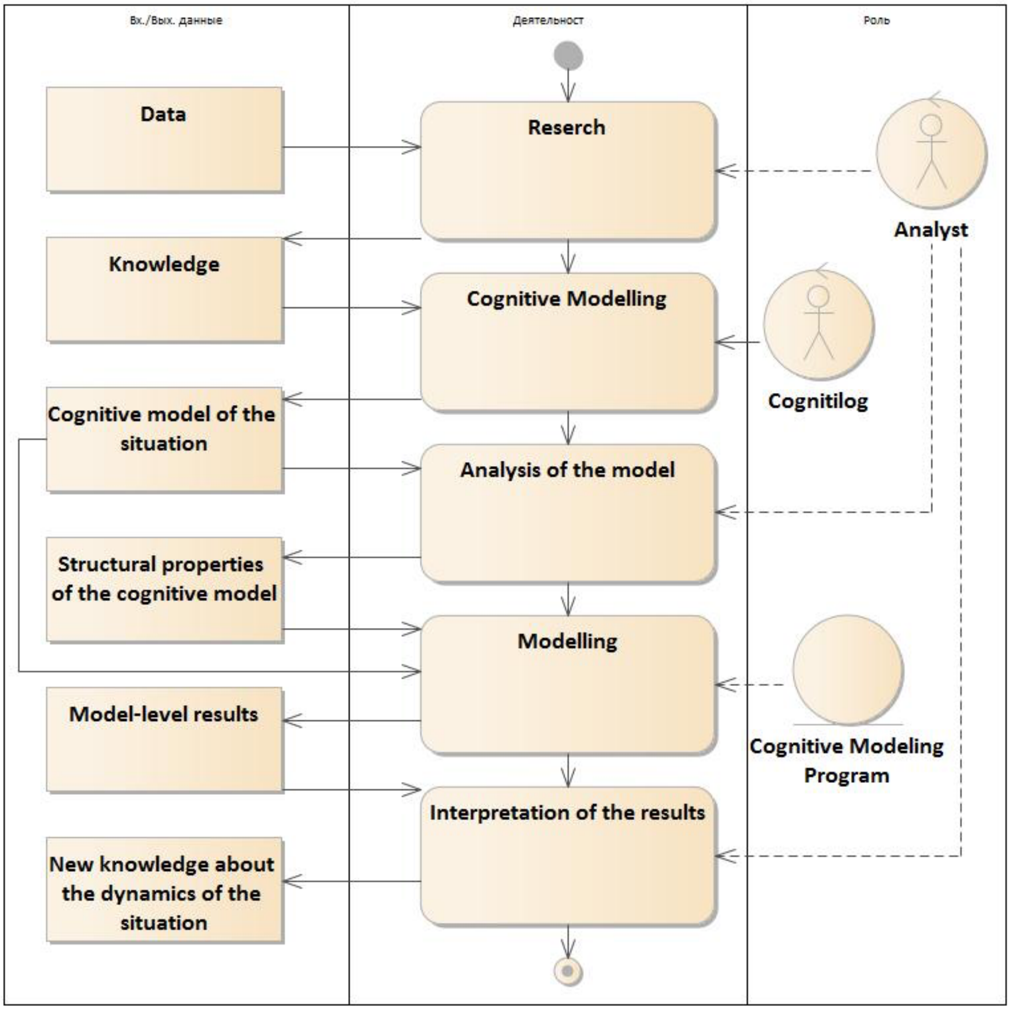

Fig. 2. Cognitive modeling technology

The technology of cognitive analysis and modeling allows to quickly, comprehensively and systematically characterize and justify the current situation in complex and uncertain situations and to offer qualitative solutions to the problem in this situation, taking into account environmental factors.

5. Use of cognitive modeling in geodynamic monitoring

Taking into account the specifics of the seismic and microseismic activity of the region it is necessary to develop a number of recommended measures to respond to an emergency. At various stages of system training, it is necessary to expand the event classifier for a more accurate response.

Accordingly, the algorithm for classifying events and training the system for geodynamic monitoring is presented below (Fig. 3).

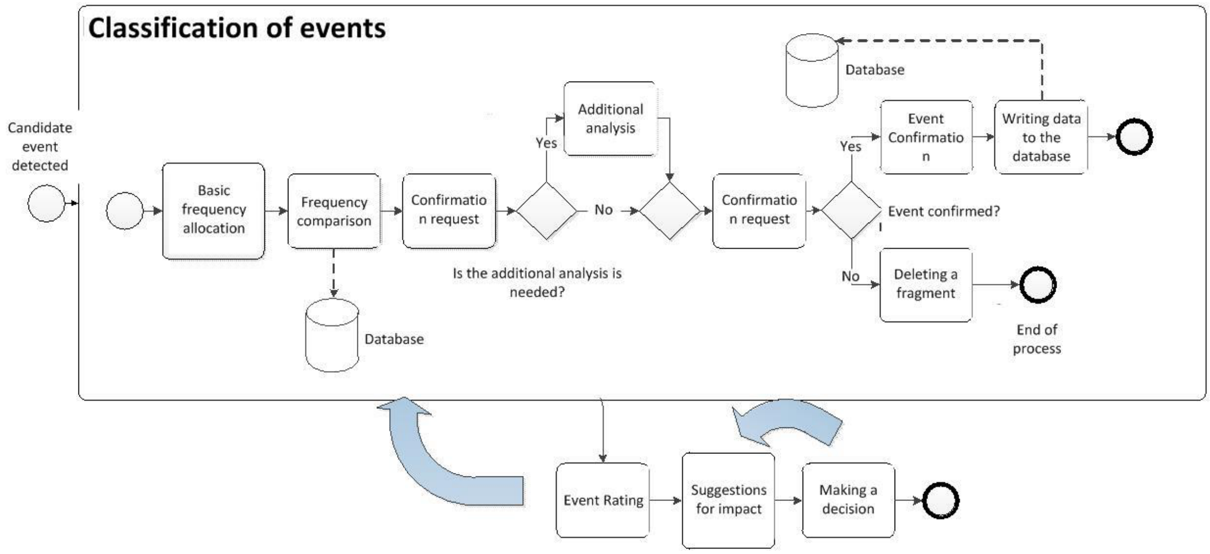

Fig.3. Event classification and system training algorithm

After the event is detected by the STA/LTA algorithm, a spectral analysis is performed, and the main frequencies that characterize the event are identified. It is necessary to take into account the frequencies of the background signal and not to take them into account when analyzing the fragment. Then, the first frequency of the event is compared with the frequencies of the event signatures from the signature database collected during the training of the system. A part of the signatures with matching frequencies is selected and the signature is chosen from the event signature database depending on the second frequency [8].

When a match is found (if a similar event was identified earlier), the new event is assigned a class. In case no match is found, additional analysis of the received event is required. Next, you need to confirm that there is no false alarm or incorrect classification of the event. If an event is confirmed, its signature is recorded in the signature image database. And then the identified event is evaluated in terms of the threat that it carries out. Based on this assessment, decisions on the impact are made.

When training the system on the basis of a classified event, the sample is trained for further classification of new events. Based on the decisions made, the impact that must be applied in the event of an emergency is adjusted.

6. Conclusion

The conducted research allowed us to obtain important empirical conclusions. Based on the study of cognitive modeling approaches, it can be argued that complex and weakly structured management decision-making tasks can be formalized by constructing cognitive maps that allow to model changes in the results of impulsive changes in factors, changes in dynamics, and the formation of scenarios. This instrumental method for the modeling of results of possible management decisions is visual and effective for the selection of the most appropriate solution.

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