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DEVELOPMENT OF SEISMIC MONITORING SOFTWARE PACKAGE ARCHITECTURE

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Conducting seismic monitoring is one of the most important tasks in seismology. It consists of seismic activity and danger assessment in a controlled area. Modern monitoring systems include both hardware complexes and software complexes. The first complexes include measuring sensors and network equipment for data exchange, and the second ones perform data aggregation, storage and processing.

Among the problems of local seismic monitoring, ineffective implementation of universal solutions is highlighted due to possible absence of required functionality and lack of territorial features consideration [1]. The solution to this problem is the development and implementation of own software package that meets the needs of local monitoring.

The aim of this work is to develop the architecture of a seismic monitoring software package that collects seismic data, processes it, and calculates various parameters allowing to assess seismic activity and seismic impact on buildings and structures of interested area.

The relevance of the work lies in the need to improve the safety of mining enterprises employees. In addition, the development of various fields of information technology makes it possible to create software and hardware systems that meet the requirements of reliability and accuracy.

The implementation of the seismic monitoring software package will allow to automate seismic data processing. Thus, it becomes possible to identify seismic danger and take measures to minimize damage from emergencies more quickly.

Complex processing of seismic data consists of many stages [2], including recording of ground movements, classification of seismic wave entries, calculation of source parameters and magnitude, calculation of earthquake intensity, calculation of damage to buildings and structures from earthquakes, etc. Each of the stages requires various methods usage, as well as taking into account many factors, including features of the studied territory.

The development of a software package for seismic monitoring involves the implementation of the following processes.

1. **Data collection and storage**. For effective testing and operation of the system algorithms, it is necessary to integrate data from global and local monitoring networks. Thanks to the development of the Internet of Things concept [3], modern seismic stations are equipped with network equipment, allowing wireless connecting receiving data in real time. Global seismic data managed by various research corporations have public access via the Internet.

It is advised to save uploaded data, calculated parameters and results of the work of software modules at various stages of seismic data processing in order to conduct further research aimed at developing new algorithms and models, as well as improving the work of existing ones. As a result, it is necessary to organize a data storage of a sufficiently large volume.

2. **Data processing and analysis**. As noted above, each stage of seismic data processing involves the usage of appropriate methods. Automation of the entire processing requires software implementation of these methods algorithms. This should include various aspects such as compatibility of software modules input and output data, sufficient computing power of target hardware system, etc.

3. **Data presentation**. Making decisions in seismology is impossible without the involvement of specialists in this field. The software package can only facilitate the decision-making process, which is difficult without a user-friendly implementation of control elements, as well as displaying software modules work results. Thus, user interface development also plays an important role in ensuring the effectiveness of the system.

Taking into account the requirements described above, the authors defined a set of software modules (Figure 1) included in seismic monitoring software package architecture. A brief description of each module is given below.

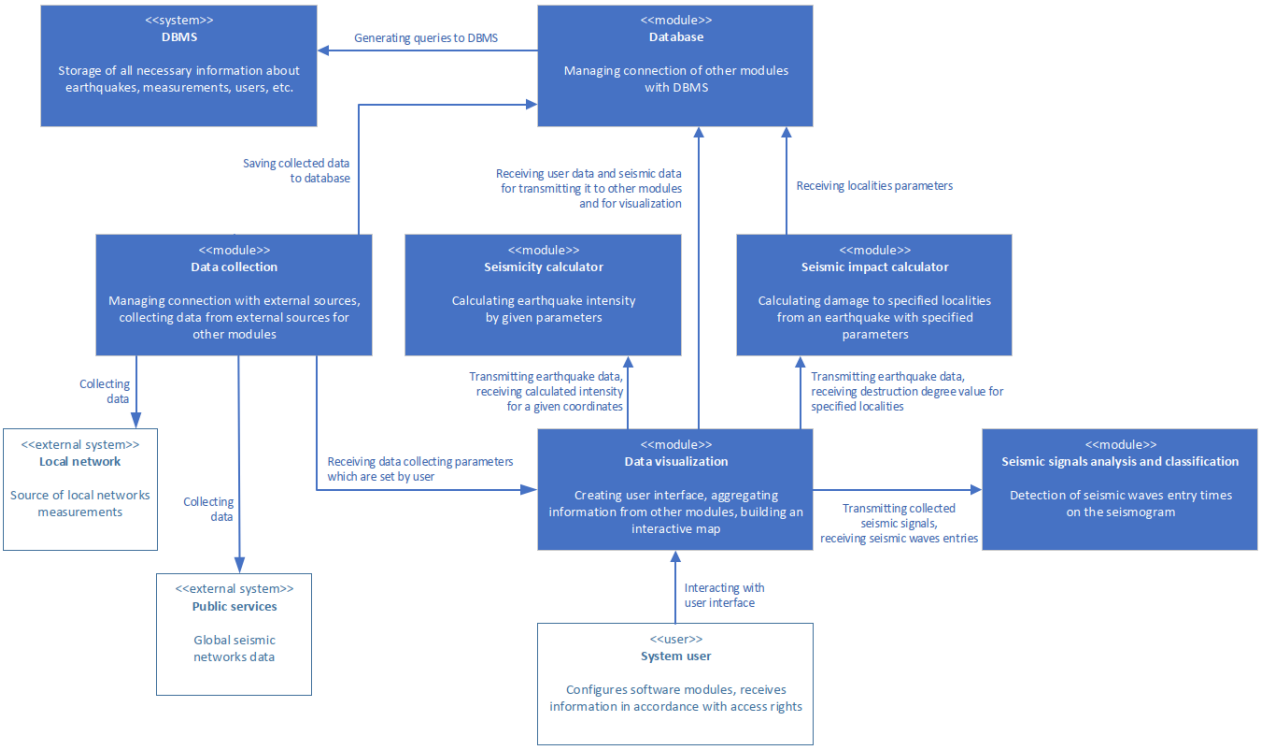

Figure 1. Software modules description scheme

Data collection module. This module is designed to organize a robust process of collecting seismic data from external sources, which include both local seismic networks and repositories of organizations providing public access to global networks. Collected data include measurements of seismographs for their later classification, archived data of earthquakes in the area of interest for testing seismicity and seismic impact calculation modules, etc.

Database module. This module implements the interaction of the other modules with the local DBMS, which stores various information: parameters of seismic stations from which measurements are collected; parameters of archived earthquakes; archive of registered seismic signals with entries of seismic waves; parameters of localities for which losses are calculated; system users' data, etc.

Seismicity calculator module. This module is designed to determine the intensity of an earthquake by a given coordinates, expressed on the MSK-64 scale. The module receives earthquake magnitude, source location and depth, as well as surrounding area parameters. The output value can be used later to calculate the seismic impact.

Seismic impact module. This module implements algorithms for determining potential damage to buildings and structures of localities from an earthquake of a certain intensity. Based on information about buildings number and type, the module determines average destruction degree for the target locality.

Seismic signals analysis and classification module. This module organizes the process of determining the seismic waves entry periods among seismic signals, which is necessary for further correct calculation of earthquake parameters. At the moment, a large number of methods for solving the classification problem have been developed. In addition, research in the field of deep learning is actively carried out, resulting in creation of several neural network models [4, 2] that solve this task.

Data visualization module. This module organizes user interaction with the system, including modules configuration, access rights allocation, modules results and reference information viewing, etc. Based on the fact that many objects in the system have spatial characteristics, it is advised to implement the interface in the form of an interactive map.

The example of interactive map for seismicity calculator is shown in Figure 2. User interface include a list of seismic events stored in local database or uploaded from external archive. Choosing parameter values allows to calculate output intensity value at earthquake source and surrounding area, including localities presented in the database. Further developing of the interface may include adding following elements:

- a set of configurable seismic stations from which seismic data is collected;
- a list of last measurements of seismic stations with detected seismic waves shown at real-time;
- a list of calculated damage from chosen earthquake to localities stored in the database.

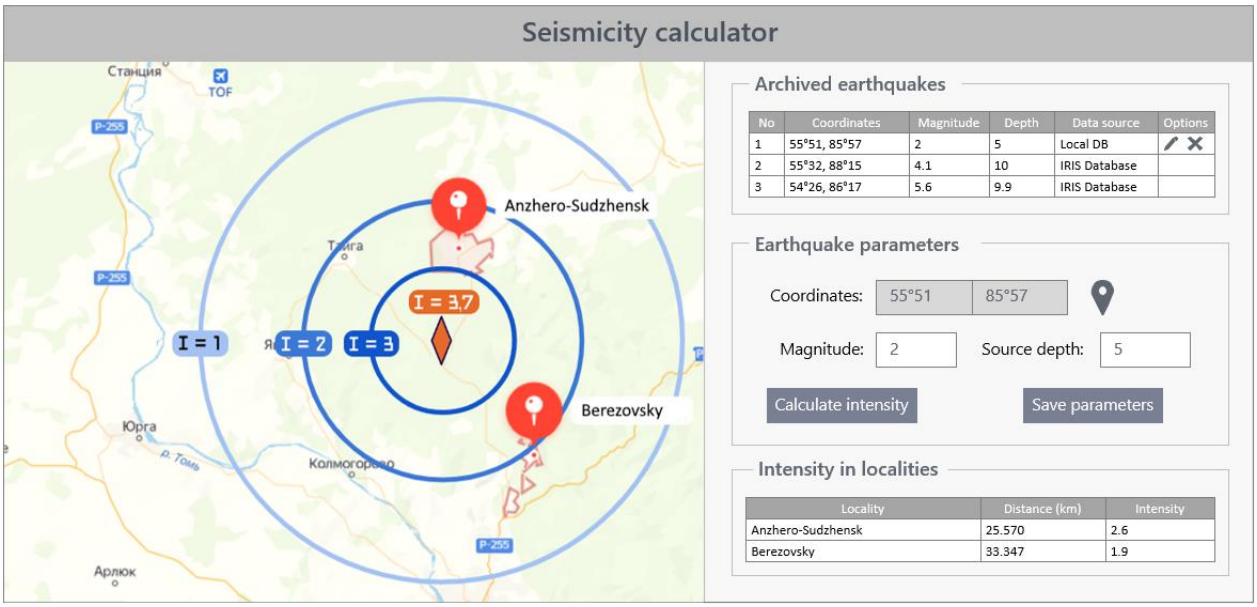

Figure 2. Example of user interface for seismicity calculator

In conclusion of the work carried out, an example of system architecture for seismic monitoring software package were proposed that includes software modules for data management, its analysis and visualization. Along with this, it is possible to implement additional modules or modify existing ones in order to improve their efficiency.

The implementation of software package described above will allow to automate the processing of seismic data and decision-making, which in turn will lead to an improvement of possible seismic hazard assessment quality and, in general, to an increase in the safety of people that lives and works in territories with seismic activity.

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