Vibroseismic Monitoring Data Management on Web-Technologies Basis

Ludmila Braginskaya
Geophysical Informatics Laboratory
ICM&MG SB RAS
Novosibirsk, Russia
ludmila@opg.sscc.ru

Valery Kovalevsky
Geophysical Informatics Laboratory
ICM&MG SB RAS
Novosibirsk, Russia
kovalevsky@sscc.ru

Andrey Grigoryuk
Geophysical Informatics Laboratory
ICM&MG SB RAS
Novosibirsk, Russia
and@opg.sscc.ru

***Abstract*—The article describes the Web-based data-processing system conceptual elements, architecture and software. The «Vibroseismic Earth Sounding» system manages field and computational experiments structured and unstructured data obtained during active vibroseismic monitoring experiments. The system provides users with search, computational, analytical and GIS services to effectively work with data.**

***Index Terms*—active seismology, databases, informational and computational systems, geographic information systems.**

I. Introduction. Problem Definition

The in-depth studies of the earth's crust started in the 1950s. In the USA and Western Europe they originated from earthquake seismology and with its methods, in particular, sparse point observations performed with a small number of seismic stations. In the USSR, deep seismic sounding (DSS) formed on the basis of seismic prospecting was widely used. The method of DSS was created by Academician G.A. Gamburtsev, who introduced into seismology the correlation principles of identifying and tracing of reflected and refracted waves. Since the 1960s, the method of continuous radiation from mechanical vibrators has been used in oil seismic prospecting. In the 1980s, powerful seismic vibrators (with an action onto the ground of up to 100 t) were created jointly by several institutes of the Siberian Branch of the USSR Academy of Sciences. With accumulation systems of recording, such vibrators create a wave effect that is equivalent to a moderate earthquake [1].

The sources of seismic signals are not only high-power technical facilities. They create a new scientific direction in geophysics — active seismology. Active seismology provides new methods for more exact and more "ecologically safe" solutions of the fundamental problems of seismology of the earth's crust structure and search for earthquake precursors [2]. The modern methods for the detection and control of variations in the parameters of elastic media in time, which are more sensitive than those in source seismology, have made it possible to formulate a large class of new problems. These are: monitoring of seismic prone zones, estimating the stressed state and anisotropy of the earth's crust and upper mantle, increasing the productivity of oil formations, controlling the seismic resistance of engineering constructions, etc.

According to experts, monitoring systems often simply accumulate large volumes of experimental data, and theoretical seismic predictions and concepts are based on obsolete information or on data accessible for researchers. Multi-year trends in geophysical fields, which can be threshold indicators of the appearance of catastrophic earthquakes, can be detected only when analyzing long-term (multi-year) data series. Therefore, the problem of accumulating the results of field experiments on vibroseismic monitoring of seismic prone zones and providing them to a wide range of researchers is very important. Modern scientific researches collectivity and narrow specialization with simultaneous diverse location of specific project participants should also be noted.

The experimental data of active vibroseismic monitoring have spatial referencing (the coordinates of sources and receivers of seismic signals). An interactive cartographic service for visualization of geographic information is very important for the researcher. The use of geo-information technologies jointly with instrumental methods of analysis provides new capabilities for data interpretation. The cartographic service, which needs comprehensive information about the terrain and passage of seismic signals, is very important for planning routes of experimental works.

Under the circumstances, it seems appropriate to organize scientific data centralized management by the actual data and programs transfer to the server for its analysis, visualization and interactive user access via Internet organization. Further, the main issues related to such systems development are considered.

II. Data Model

A structured tabular (relational) data or metadata organization usually causes no difficulties. The relational model and SQL language, underlying modern DBMS, are ideal for this. Such organization is more difficult for the data received from the sensors and numerical models in the course of the experiment. Such data are n-dimensional, in the general case, numerical arrays, which can't be structured and therefore not directly supported by RDBMS.

978-1-5386-1596-6/17/$31.00 ©2017 IEEE

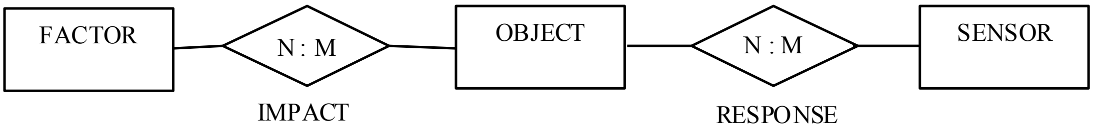

Fig. 1. The conceptual model of the experiment

Currently, for both relational and non-relational data management primarily used either architectures:

- both relational and non-relational data stored in the database;
- relational data stored in the database, and non-relational data – on file systems or file servers.

Each of these approaches has its advantages and disadvantages. In first case, the one database becomes a convenient centralized repository for both data types. However, in this case, non-relational data is stored in binary large objects (BLOB) and the access speed to these objects is greatly inferior to the access speed to the file system. The second approach provides high-speed access, but at the same time complicated application development and management, as applications must maintain coherence between the database records and the files associated with these records. This problem can be partially or completely solved by creation the data model that provides an efficient indexing of the file system in the database.

When constructing the subject area model, we assumed that the experimentally investigated object can be assigned a certain set of parameters corresponding to representations of researchers on the state and behavior of the object. The parameters are what can be measured, monitored, and modified in the research process. The object is affected by some influence factors with controlled parameters in the course of experiments. And a number of object parameters is recorded using sensors with simultaneously fixation of other parameters. So the conceptual experiment model can be represented by ER-diagram ("entity-relationship") shown in Fig. 1.

The diagram contains three classes of entities: OBJECT, FACTOR and SENSOR. Each class has a set of attributes defined by a specific area of research. Entity relationship expressed by two classes of bonds: IMPACT and RESPONSE. Entity class FACTOR may be missing in the case of passive experiment or observation.

Further, we replace entities and relationships of ER-diagram to the corresponding relations R with primary keys K and attributes A to move to the relational data model:

OBJECT – R1 (K1, A11, A12, ..., A1n);
FACTOR – R2 (K2, A21, A22, ..., A2n);
SENSOR – R3 (K3, A31, A32, ..., A3n);
IMPACT – R4 (K1, K2);
RESPONSE – R5 (K1, K3).

Auxiliary relations R4 and R5 are used for organization of communication type M:N (many-to-many) between R1, R2 and R1, R3 relations respectively. Primary keys K are, for example, the serial numbers of corresponding relations tuples. In general, the key attributes must contain values of finite sets P:

P1={ K11, K12, … , K1m };
P2={ K21, K22, … , K2m };
P3={ K31, K32, … , K3m }.

The model allows organizing file archive addressing, having the following hierarchical structure:

/ data / P1 / P2 / P3 / P1 P2 P3 N (1),

where string «P1 P2 P3 N» is the data file name, formed by concatenating the attributes P1, P2, P3 and the sensor N channel number for a multichannel sensors. This structure corresponds to the native tree structure of the file system.

The proposed data model in combination with the addressing method of unstructured data provides a monosemantic native connection between the records in the database and the relevant files. At the same time, users can completely disengage from the files and directories names or patterns of names, working only with the attributes, cataloging the properties and the source of each file.

As a model experiment, the data model is generalized. It must be adapted to each specific scientific area and type of experiments. In most cases, the decomposition of relations OBJECT, FACTOR and SENSOR may be required considering functional dependencies between attributes.

III. Block Diagram

The block diagram of the data-processing system, implementing the above concepts of scientific experiments data management, presented in Fig. 2. Users interact with the system using a standard Web-browser, sending requests for search, analysis and visualization of data. In the search query user sets parameters of the object, factors, affecting the object, and the sensors, that recording data. The request for analysis should contain the list of analysis procedures and parameters of these procedures, applied to the found data.

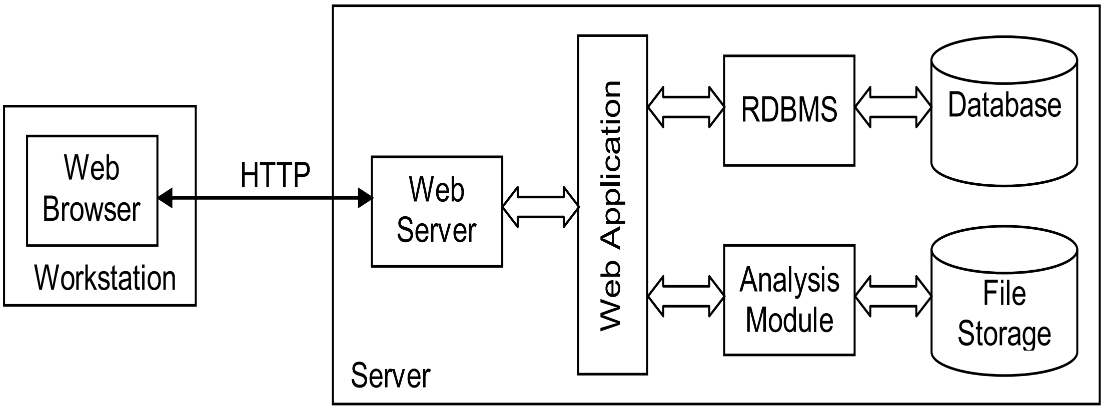

Fig. 2. The block diagram of the data-processing system.

The attribute data, needed to access the file archive, are retrieved from the database as a result of the search query. The web-application generates the files address in accordance with (1) and sends them to the analysis module, based on these data. Analysis module is the application that performs data analysis in accordance with the algorithms used in the specific field of experimental studies. In most cases, it is classic and special mathematical and statistical procedures for analyzing multidimensional numeric arrays [3, 4]. To ensure adequate performance for on-line mode data processing the computationally intensive procedures can be performed by software and hardware module based on CUDA architecture. The module uses graphic processors (GPU) and math libraries of NVIDIA. Due to multi-core parallel architecture GPU outperforms general purpose processors (CPU) 1-3 orders for the most of the computational procedures.

The resulting after analysis numeric arrays returned to the web-application, which is creates graphs, tables, text "on the fly" and sends it all to the user in the form of web-page. Final information representation is realized by using client technologies (JavaScript, HTML and CSS style sheets).

Specific hardware and software implementation of the Fig. 2 block diagram determined by the size of the system, the complexity of the analysis algorithms, the number of users, etc.

IV. The "Vibroseismic Earth Sounding" System

Based on the above concept, the database and the web-oriented data-processing system "Vibroseismic Earth Sounding" was developed by the authors. The system is designed to manage the experiments data in the area of the lithosphere active vibroseismic monitoring. The experiments were conducted during 1995-2016 's by institutes of the Siberian Branch of the Russian Academy of Sciences in collaboration with other Russian and international scientific organizations.

The system provides the following basic functions:

- the detailed information (metadata) about any of the experiments obtaining;
- the database search simultaneously by 18 vibrosounding parameters (source types, signals type and parameters, geographic coordinates, etc.);
- the interactive on-line found seismic traces analysis (correlation, spectral, spectrally-time, etc.), displaying results directly in the user web-browser;
- interactive maps and satellite images with seismic waves sources and recorders, building on the basis of the search results.

The system can be used by scientists and engineers employing the methods and theoretical and experimental data on active seismology, by students specializing in this field, and by specialists estimating the state of the art in this scientific area of research.

The system is currently available on the Internet at http://opg.sscc.ru. An example of the system page with map and display of the recorded vibroseismic traces of the Baikal region is shown in Fig. 3.

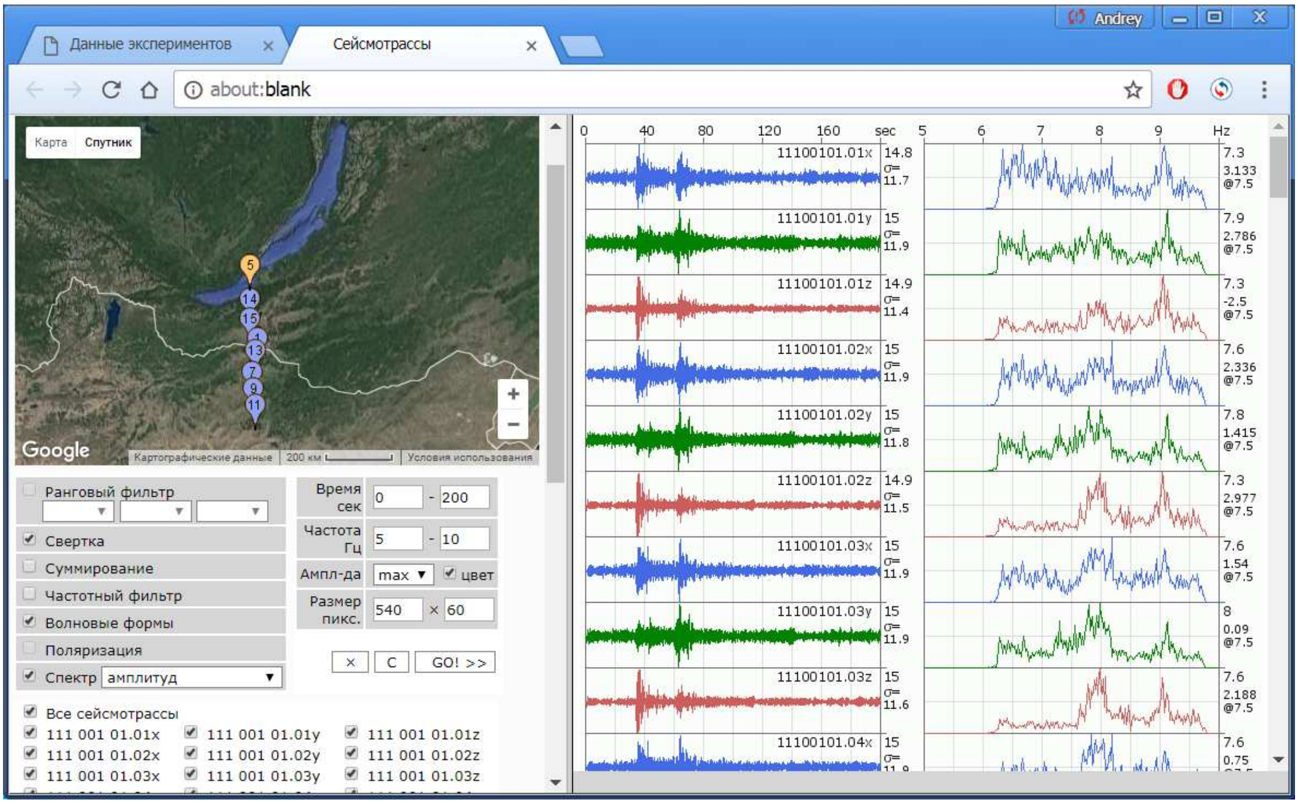

Fig. 3. An example of the system page with map and display of the recorded vibroseismic traces of the Baikal region.

ACKNOWLEDGMENT

This work was supported by RFBR grant № 15-07-06821-a, project №16.6 of the Presidium of Russian Academy of Sciences.

REFERENCES

[1] Alekseev A.S., Tsibulchik G.M., Kovalevsky V.V., "The basis of the theory of active geophysical (multidisciplinary) monitoring. Conception of source and surface dilatant zones," Handbook of Geophysical Exploration: Seismic Exploration, Active geophysical monitoring, 2010, vol. 40, pp. 105–133.

[2] Alekseev A.S., Glinsky B.M., Kovalevsky V.V., Khairetdinov M.S., Active vibromonitoring: experimental systems and fieldwork results. Handbook of Geophysical Exploration: Seismic Exploration, Active geophysical monitoring, 2010, vol. 40, pp. 55–71.

[3] Grigoruk A.P., Znak V.I. "Network Processing of Vibroseismic Data Using the WOS Fiters" Proceedings of the IASTED International Conference Automation, Control, and Information Technology – ACIT 2010, June 15 - 18, 2010, Novosibirsk, Russia, ACIT-ICT 2010 pp. 5-8.

[4] Grigoruk A.P "Wavelet filtration of the vibroseismic signals" Proceedings of the Third International Forum on Strategic Technologies – IFOST-2008, Novosibirsk-Tomsk, Russia, June 23-29, 2008, IEEE, pp. 276-279.