An Ontological Approach to Organizing
an Active Seismology Web Environment

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Abstract. At present, an approach to constructing knowledge-based information systems in which access to data is organized on the basis of ontologies is being actively developed. This approach makes it possible to combine a relational base for data storage with an ontology representing a conceptual system of the subject area. This paper proposes a technology for organizing a web environment for research in the field of active seismology, which allows, on an ontology basis, to present the contents of a data source to the user at a conceptual level and to address user requests to several heterogeneous data sources. High efficiency of executing requests for access and analysis of experimental data is provided by a relational database management system.

Keywords: active seismology, ontology, information systems, relational databases

1   Introduction

Active seismology is a direction of geophysics in which the Earth's crust structure and geodynamic processes in zones of earthquakes and volcanoes are studied using controlled sources of seismic waves: explosive, hydromechanical and electromagnetic pulsed sources, as well as powerful seismic vibrators [1]. The possibility of in-depth studies of the Earth's interior using powerful vibration sources was theoretically justified and put into practice in the 1970s – 80s. The vibroseismic methods have important advantages over the passive seismology methods. These are the exactly known place and time of the source, radiation of a seismic impulse of a predetermined shape, computer control of the experiment, common use, and environmental safety. The vibroseismic study is a science-based activity, which includes:

- development of hardware and software to control technical complexes for radiation and registration of vibrational signals;
- development of a theoretical basis of the method, in particular, inverse problems of the theory of elastic wave propagation, direct problems of modeling seismic wave processes, development of a theory of multidisciplinary vibroseismic monitoring, etc.;
- experimental field studies on registration of wave fields from powerful sources at considerable distances (several hundred kilometers);
- development of algorithms and programs for experimental data processing;
- numerical simulation of full wave fields in complex environments using supercomputers;
- development of engineering-seismological technologies for studies of buildings and large industrial structures.

The efficiency of active seismology investigations depends not only on efficient organization of access to relevant knowledge and data directly related to a given subject area, but also on the integration of heterogeneous data and knowledge of specialists in related science fields. The important direction of research in active seismology - mathematical modeling of full wave fields - is associated with choosing adequate models of the Earth's crust obtained by various geophysical methods. The interpretation and expert evaluation of the results of active seismology experiments require a lot of reference and other text materials. Efficient planning of field experiments on the registration of wave vibroseismic fields depends not only on the availability of the data of observations (if they have already been carried out in the region of expected works), but also on additional information about the region; in this case convenient user GIS services are especially important.

With many heterogeneous data sources available, there arises the problem of organizing an infrastructure which allows not only to accumulate information for its reuse in various studies, but also to systematize the knowledge and data of the subject area, to provide an informative access and preliminary analysis of the data. This paper proposes an approach to organizing a scientific infrastructure for storing, presenting, formalizing, and systematizing information, as well as providing high-speed access and analysis of numerical data. The infrastructure proposed by the authors

combines the subject area ontology to integrate heterogeneous information resources without their physical merging and a relational database that provides efficient storage and processing of structured data.

2   Experimental Data Management

Experimental works on vibroseismic monitoring have been carried out by ICM&MG SB RAS since 1985. As a result of many years of observations (more than 50 field experiments), a unique data set (more than 40,000 waveform files) has been accumulated.

To manage vibroseismic monitoring data, an information-computing system (ICS) "Vibroseismic Earth's Sounding" [2] has been developed. It includes an archive of waveform files and related information (seismic source type, parameters of radiated signals, parameters of the recorder, geographical coordinates of the source and recorder, etc.).

The core of the ICS is a relational database (DB). The database stores structured information (Fig. 1) describing the experimental data. The EXP table contains a list of experiments and their brief description. Each of the experiments on vibroseismic Earth's sounding is carried out with a fixed arrangement of the sources of seismic waves (the IST table) and registrators (the RGR table) involved in the experiment. During the experiment, vibroseismic sessions are performed. The SEANS table contains the date and time of the source operation. The SIGNAL table contains a set of parameters describing the properties of radiated signals. Each session corresponds to one sequence of relations GENER and several (according to the number of registrators) sequences of relations REGA. In accordance with the specified relations, the GENER and GENA tables establish a one-to-one correspondence between a specific session and the signal parameters, and the REGA table establishes the correspondence between the session and the recorder.
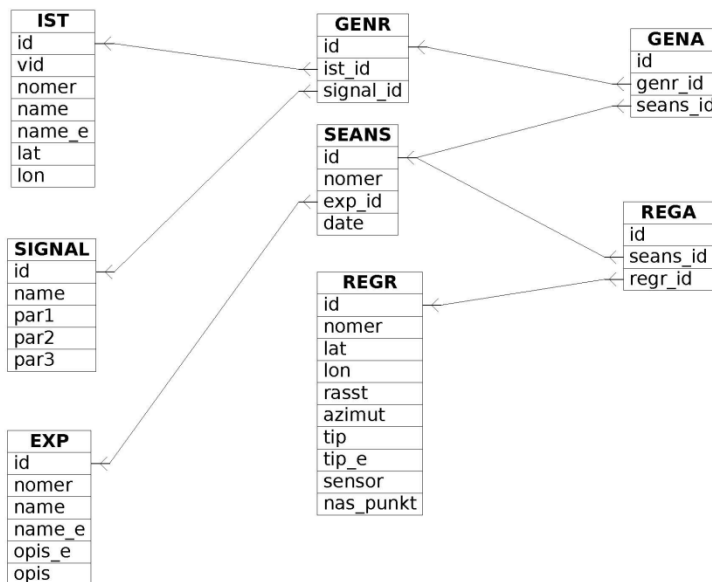

Figure 1. DB structure.

Each table contains one key field whose contents are unique for each entry in this table. Using the key field, the records in the table can be uniquely identified. In response to a user request, which can contain any values of the parameters of interest (up to 20 parameters), the ICS generates a set of database identifiers: EXP_id / SEANS_id / REGR_id.

This model allows one to organize addressing the file archive having the following hierarchical structure:
 / Registrator number / Session number / Experiment number / <waveform files>.

A user request for analysis (Fig. 2) must contain a list of analysis procedures that will be applied to the found data and the parameters of these procedures.

As a result of execution of the requests, data are extracted from the file archive and transferred to the analysis module. This application performs data analysis in accordance with the algorithms used in a specific area of experimental research. To ensure an operation speed sufficient for the online mode, the application is written in C ++ using the Intel Performance Libraries. The resulting numerical arrays are returned to the web application, which quickly generates graphs, tables, and text and sends all this to the user in the form of a web page.
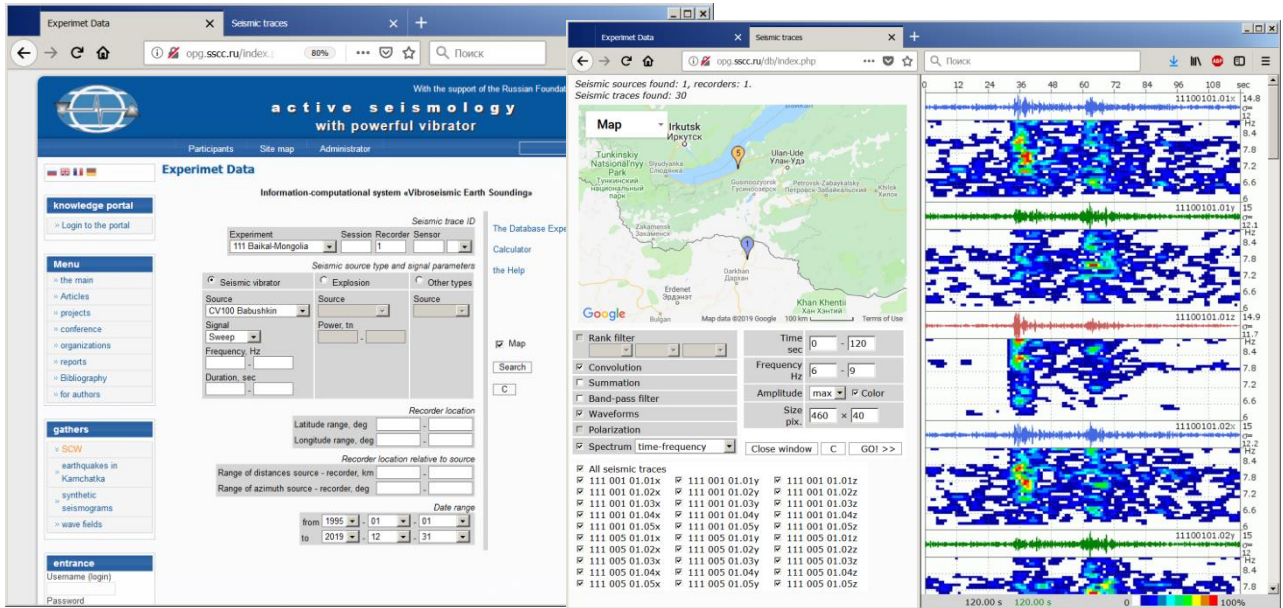
Figure 2. Search form and request results.

3 Integration of Knowledge

Integration of subject area (SA) knowledge on "active seismology" and navigation through the Internet are carried out by the knowledge portal. The core of the information model of the portal in question is the SA ontology on active seismology developed by the authors [3].

The knowledge portal [4] provides a holistic view of the knowledge about the subject area, establishes interrelations between events related to this science, objects, results and methods of investigations, and provides access to them via the Internet. The portal ontology introduces formal descriptions of the subject area concepts in the form of classes of objects and relations between them, thereby defining structures for representing real objects and their relations. In accordance with this, the data on the portal are presented in the form of a semantic network, i.e. as a set of diverse interrelated information objects. Figure 3 presents a fragment of the active seismology ontology describing the "Baikal-Ulan-Bator Experiment 111" of the class "Field Experiments".
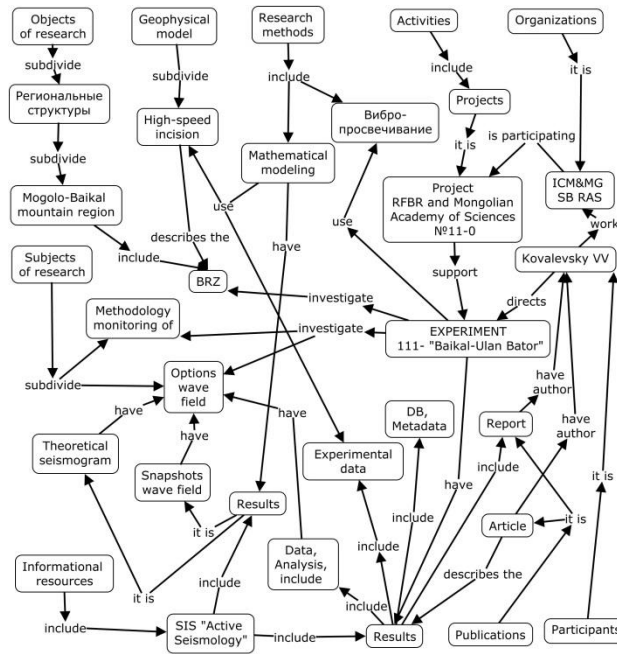

Figure 3. Fragment of ontology.

Informative access to the systematized knowledge and information resources is provided using the developed navigation and search tools provided by the portal, whose functioning is also based on the ontology. Fig. 4 shows the portal page corresponding to the ontology fragment in Fig.3.

Object communications

hasAuthorResultOrganization

Organizations
Geological Institute of SB RAS
Institute of Computational Mathematics and Mathematical Geophysics SB RAS (ICMMG SB RAS)
Buryatia Division of Geophysic Survey of the Siberian Branch of the RAS
Mongolia Research Center for Astronomy and Geophysics (RCAG)

hasAuthorResultPerson

Persons
Avrorov (S.A.)
Braginskaya (L.P.)
Grigoruk (A.P.)
Kovalevsky (V.V.)
Odonbaatar (S.)

conduct research

Object of Study
Baikal rift zone and adjacent Mongolian areas

contains a description (metadata)

Databases
DB "Experiment-111"

contains data

Experimental data
111 - experiment #111 data (analysis, visualization)
101 Elbrus-2010 Experiment. Map. Description.

contains modeling results

ScientificResult_Product
Babushkin (Baikal) - Ulaanbaatar (Mongolia) profile wavefield
Babushkin (Baikal) - Ulaanbaatar (Mongolia) profile theoretical seismograms

contains results

InternetResource
SIS "Active Seismology"

Reverse object communications

usesProjectResult

Project
SB RAS Project 4.9 "Studies of the structure of the earth's crust and geodynamic processes in the southern part of the Baikal rift zone and northern Mongolia by vibroseismic methods"
RFBR and Mongolian Academy of Sciences joint project No. 11-05-92215 "Investigation of the characteristics of the wave field of a powerful vibrator for the purpose of vibroseismic sounding of deep structures of the Mongolian-Siberian region"

describesResult

Publications
H. Thybo Lower crustal intrusions beneath the southern Baikal Rift Zone: Evidence from full-waveform modelling of wide-angle seismic data
Karavaev (DA), Kovalevsky (VV), Fatyanov (AG) Verification of the speed models of the Earth's crust of the Baikal Region, constructed by the experiment BEST and PASSCAL
Braginskaya (LP), Grigoruk (AP), Kovalevsky (VV), Tubanov Vibroseismic research on the 500-km profile of Babushkin (Baikal) - Ulan-Bator (Mongolia)
Braginskaya (LP), Kovalevsky (VV) Report on field expedition work on the Ulan-Ude - Ulan-Bator profile
Mordvinova 3D model of the South of the Baikal Rift Zone and adjacent territories by exchange waves
Total: 6

containsActivitiesRresult

Activities
SB RAS integration project No 54 "Development of methods for mathematical modeling of geophysical fields and experimental studies of geodynamic processes in seismic and volcanic zones"
Presidium of the RAS Program No 4. Natural environment of Russia: adaptation processes in a changing climate and development of nuclear energy. IVM & MG SB RAS Project No 4.9. Natural environment of Russia: problems of modeling of seismic zones, monitoring of environmental pollution and climate change. 2012-2014
SB RAS Project No 4.9 "Studies of the structure of the Earth's crust and geodynamic processes in the Southern part of the Baikal Rift Zone and Northern Mongolia by vibroseismic methods"
RFBR and Mongolian Academy of Sciences joint project No. 11-05-92215 "Investigation of the characteristics of the wave field of a powerful vibrator for the purpose of vibroseismic sounding of deep structures of the Mongolian-Siberian Region"

Figure 4. Portal page.

The information objects are represented on the portal page by hyperlinks. Via the hyperlinks the knowledge portal allows addressing the ICS "Vibroseismic Earth's Sounding". Addressing the experimental data and analysis resources is made inside the ICS shell by forming a request (Fig. 2).

4   Conclusions

The developed web environment on active seismology provides integration of thematic information resources and informative access to the results of field and computational experiments on active vibroseismic monitoring, interactive data analysis, and automatic construction of interactive maps of field work regions. The interrelationship between the works of researchers, the results of these works, and the people and organizations engaged in the research in the field of active seismology is provided by the knowledge portal. The core of the knowledge portal is an ontology constructed by a group of experts working in various areas of active seismology. The ontology is used for convenient

navigation through the scientific knowledge and efficient search for data and resources for their analysis. The Internet resource is available at http://opg.sscc.ru/.

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