Scientific Internet Resource for the Geophysical Research Support

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Abstract — **The paper presents a scientific Internet resource that provides the systematization of the knowledge and information resources of the geophysics research that use the active seismology methods. Systematization and structuring of knowledge and the subject area data is carried out on the basis of ontology. The Internet resource contains vibroseismic monitoring databases and the tools for their computational analysis, the results of numerical modeling of vibroseismic wave fields, the information about scientific organizations and persons developing the active seismology methods, publications containing the results of research in the subject area, reference and other information necessary for the interpretation of vibroseismic monitoring data. Information on the resource is presented in the form of a network of interconnected information objects. The user gains access to knowledge and data by navigating the ontology concept tree.**

Keywords — ontology, data analysis, knowledge integation, scientific information systems

I. Introduction

The increase the number of natural and man-made disasters on the Earth in the recent decades, is one of the global problems of our time. Today, the natural disasters occur in the world four times more often than 30 years ago, their consequences are becoming more devastating, and the number of victims is growing. The number of victims in the world from destructive natural phenomena has been increasing in recent years annually by 4.3%, and the number of victims — by 8.6%. Economic losses are growing by an average of 6% per year. According to UN estimates, over the past 45 years, natural disasters have killed more than 3.5 million people, and the economic loss amounted to $ 2.8 trillion. [1].

Earthquakes are among the most dangerous natural disasters on our planet. The increase in the number of the earthquake victims is directly related to the increase in the number of strong earthquakes with a magnitude of more than 6.5. The strongest earthquakes occur at the tectonic plates boundaries associated with subduction, active collision, or active faults.

Volcanic eruptions and earthquakes are the different forms of development of geodynamic processes in the Earth. The analysis of the dynamics of the number of volcanic eruptions from 1900 to 2020 shows, that there is a tendency for an increase in the number of volcanic eruptions.

Seismically active zones cover vast areas of Russia. About 25% Russian Federation territory with a population of more than 20 million people can be exposed to earthquakes of magnitude 7 and higher. [2]. Seismic hazard is characterized by a general increase of the seismicity level in recent years in the following zones: Far Eastern, Caucasian, Baikal and Altai-Sayan.

Recent studies show that in the territories that were considered seismic passive, weak seismic events with a magnitude of up to 3–4 are possible. They can provoke ecologically dangerous destruction of industrial, transport and residential facilities [3].

New data on the technogenic seismicity have appeared in recent decades. They indicate that the earthquakes with a magnitude of M> 7 can occur within the most ancient platform areas. The Bachat earthquake M = 6.1 occurred in 2013 in the area of the intensively developed coal deposits of Kuzbass. It is noted that the Bachat earthquake was the largest man-made earthquake in the areas of solid minerals production [4]. As a rule, the centers of man-made earthquakes have shallow depths, which increases their danger to buildings and structures.

Seismoacoustic effects from industrial explosions, as well as from explosions associated with the disposal of ammunition, also pose significant risks to humans and the environment [5]. The study of explosions in open quarries is of particular interest, since it is possible to solve many seismological and environmental problems on their basis.

In the context of growing risks from earthquakes and other dangerous natural impacts, the task is to create a scientific monitoring system that will allow us to make the prognoses of the possible manifestations of crisis phenomena. In the concept of monitoring observations, the emphasis is on identifying the relationship between seismic activity and anomalies of geophysical fields of various nature.

Academicians of the RAS Alekseev A.S. and Goldin S.V. proposed an approach to the organization of multidisciplinary geophysical monitoring using vibroseismic technologies

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[6,7]. Changes in the variations in the characteristics of the seismic wave field are monitored in the process of sounding the source zones by powerful low-frequency seismic vibrators in this type of monitoring.

Vibration sources provide stable radiation of seismoacoustic signals with specified parameters, which allows one to use them as the test signals for a wide range of tasks, including those related to the assessment of geoecological risks during blasting operations.

The information obtained in the experimental vibroseismic work is rather complicated for its interpretation and requires computer processing, computational analysis, and mathematical modeling of wave fields in a complexly constructed environment. Solving these problems requires the use of the latest supercomputer technologies.

The significant integration of both spatial and nonspatial data from various participants of the monitoring process is required for effective use in geophysical studies the results of field and numerical experiments on vibroseismic monitoring, as well as mathematical modeling.

This paper presents a scientific Internet resource that provides a systematization of knowledge and information resources about research in geophysics that use the active seismology methods.

II. Methods and materials

The success of the joint work of researchers who are geographically dispersed, represent different scientific fields, requires appropriate integration of data posted on various sites, electronic libraries, etc.

The complexity of the search, access and reuse of experimental data, the barriers to the semantic compatibility of various kinds of information create a problem for cooperation between specialists dealing with the problems of seismic processes monitoring.

Nowadays, it has become a common practice to describe subject areas using ontological models. The main purpose of ontology creation is to provide support for the accumulation, sharing and reuse of knowledge. For the first time the term “ontology” was introduced into knowledge engineering by Thomas Gruber [8]. According to its definition, an ontology is an explicit specification of conceptualization. Conceptualization here means a simplified description of some part of reality, built for a specific purpose. With regard to a specific subject area, this description should consist of terms and rules for the use of these terms, limiting their meanings within a specific area. At the formal level, an ontology is a system consisting of a set of concepts and a set of statements about these concepts. The concepts can be combined into classes and relationships between them can be built on this basis.

There are numerous works on the development of ontologies for representing knowledge about earthquakes and related expert systems for risk assessment [9,10].

However, these ontologies do not fully describe all the concepts associated with multidisciplinary geophysical monitoring. In addition, most of the ontologies presented in publications related to geophysical research are not published in semantic repositories, so it is impossible to extract knowledge from them for reuse.

A scientific Internet resource, which is an intellectual environment for supporting geophysical research in active seismology, was developed at the Laboratory of Geophysical Informatics, ICM&MG SB RAS for the integration of data and knowledge in this area. The Internet resource was created on the basis of the Scientific Information System (SIS) "Active Seismology" and the Knowledge Portal "Geophysical Monitoring" (KP) [11].

Today there is no strict definition of data, metadata, information and knowledge. In the presented concept of the scientific environment, we consider data the records of signals obtained in the field works and computational experiments and represented by files that make up a directory tree. Metadata — description of experiments (type of seismic source, parameters of the radiated signal, recorder parameters, geographic coordinates of the source and recorder, etc.), represented by relational databases. It should be said that the description of data is reduced to a certain limited set of parameters. In our case, these are 18 parameters: Source Type, Source Number, Experiment Number, etc. The relational database management system provides [12] high performance of requests for access and analysis of experimental data.

Scientific Information System “Active Seismology” contains experimental data obtained in the long-term active seismic monitoring of seismic hazardous zones in Altai-Sayan region, Baikal rift zone and Northern Mongolia, Elbrus volcano and mud volcanoes of the Taman mud volcanic province. The seismic wave fields radiated by powerful stationary and mobile seismic vibrators were recorded, as well as seismic emission from active volcanoes. The SIS also includes the records of the signals from the powerful calibration chemical explosions at the Semipalatinsk nuclear test site, industrial explosions at the mines and open quarries in Kuzbass, explosions at the Shilovo test site in Novosibirsk region, and records of seismic noise from the ground vehicles. These data are of interest for studies related to geodynamics, seismic hazard and geoecological monitoring.

We refer individual sites, publications, reference information, etc., located on the Internet to information objects. SIS “Active Seismology” includes a thematic electronic resource library (EL), which allows all registered users to publish their own materials. In particular, the electronic library includes reference materials, expedition reports, articles previously unpublished on the Internet.

Knowledge Portal integrates thematic sites and publications from disparate Internet resources in addition to the informational materials contained in the EL

The selection of articles was made by us by the method of "inclusion" and "exclusion". First, a corpus of articles was selected on the thematic sections: the geophysical monitoring: seismic monitoring, monitoring of radon emanations, etc. A pilot search for articles was carried out in various libraries using keywords. Then experts from different areas of monitoring checked the list of articles, adding to it or excluding some publications. The criteria for inclusion of articles were thematic accordance, relevance and reliability.

The exclusion criteria are insufficient reliability of the source of information and repeatability.

We refer to knowledge of the subject area (geophysical monitoring) the set of information that forms a holistic description corresponding to a certain level of awareness of the issue being described. An ontology can form a framework for a knowledge base, create a basis for describing the basic concepts of a subject area, and serve as a basis for integrating databases containing factual knowledge necessary for the effective work of researchers. Each information object must be assigned to a certain class of ontology, i.e. be an instance of it. Relationships can exist between information objects, the semantics of which is determined by the relationships specified between the corresponding classes of the ontology. In an ontology, databases or their individual elements can be described as information objects.

When organizing the ontology and the knowledge portal for geophysical monitoring, the methodology and technology of the Laboratory of Artificial Intelligence ISI SB RAS was used [13,14]. This technology supports the development of portals focused on working with a variety of heterogeneous resources or data sources on a specific scientific topic. According this technique, the problem area is described in the form of two basic ontologies: the Ontology of scientific knowledge and the Ontology of scientific activity. The ontology of scientific activity contains such concepts as Research Object, Research Method, Research Subject, Task, Result, Publication. The ontology of scientific activity contains the concepts: Organization, Person, Event, Activity. The use of ontologies makes it possible to make the KP development process more technological, in particular, to use previously obtained and formalized knowledge.

Meta-concepts of the ontology were expanded with concepts that describe geophysical monitoring and its components. To build basic hierarchies, a corpus of publications, containing a systematization of concepts related to geophysical monitoring was worked out, and interviews with experts working in various areas of the subject area were conducted. Each of the built hierarchies was assigned to one of the meta-concepts of the knowledge ontology for ordering the concepts.

The structure of the technology for building knowledge portals includes redactors of the data, ontologies and relations. The ontology editor is used for creation a formal specification of an ontology, including: hierarchies of concepts; a set of relations defined on the basis of concepts; a set of attributes describing the properties of concepts and relationships; a set of domains that define attribute values; a set of restrictions and axioms that describe the properties of classes and relationships.

III. RESALTS

The knowledge portal of the geophysical monitoring has been created in order to integrate the heterogeneous data of geophysical research which use vibroseismic methods of the Earth’s sounding. The information basis of the knowledge portal is the ontology, which ensures the consolidation of resources into a common information space, and meaningful access to them via the Internet. The knowledge portal provides an opportunity to search for information on various aspects of scientific activity simultaneously (for example, searching for information about organizations or scientists developing some research methods in geophysics). From the user's point of view, the portal is a thematic Internet resource that provides the ability to search and view information within a subject area (geophysical monitoring).

The information content of the portal includes both the general knowledge contained in the ontology and the specific knowledge about real objects.

When a concept class is creating, its unique name and a set of attributes that are used to set various properties are specified. A parent from previously created classes can be selected for a class. In this case, not only all attributes and relationships are inherited from the parent class, but the parent itself is associated with the new class by the class – subclass relationship.

Ontology relationships are binary. A name, an admissible values area and the number of possible values are specified for each attribute of a class.

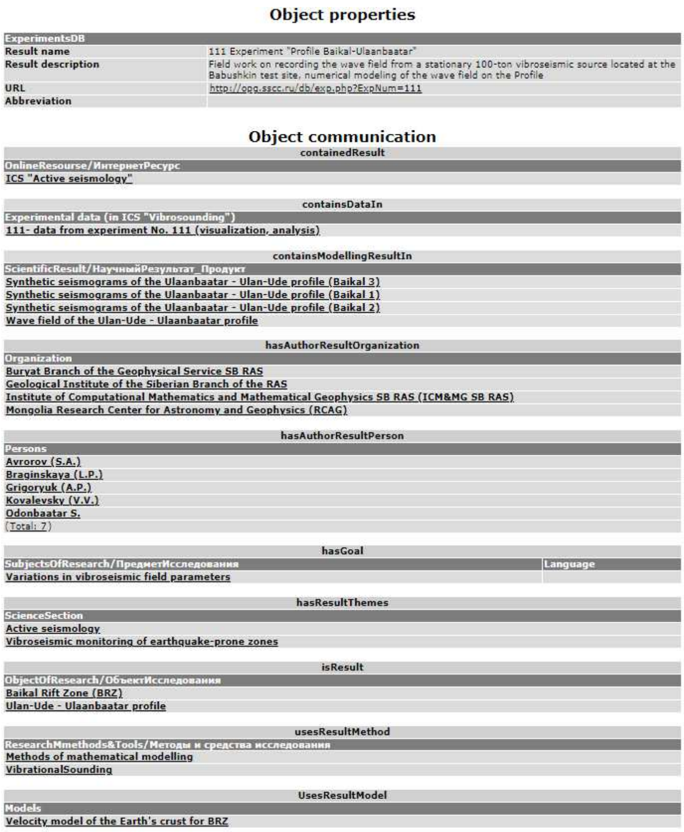
The concepts combined into the class “Scientific result” are one of the most important concepts of the ontology of geophysical monitoring. This class is used to describe the results of scientific activities of the geophysical monitoring. Specimens of the class are the descriptions of experiments, field experimental data, theoretical seismograms, images of wave fields, models, revealed patterns, etc. Discoveries, new laws, theories, historical facts are also classified as Scientific result. Properties of concepts of this class are represented by attributes: result name — a mandatory unique attribute of a string type; description of the result — an attribute of a string type, which gives a short textual description of the result; date of receipt — an attribute of the date type used to fix the date of receipt of a scientific result. This class of concepts is divided into the following subclasses: experiments, experimental data, models, simulation results, facts.

All information about a specific object and its links is displayed in the form of an HTML page. The objects associated with the main object are presented on its page in the form of hyperlinks, by which you can go to their detailed description.

The Knowledge Portal page containing the description of the experiment “111. Baikal–Ulan Bator profile” is presented in Fig. 1. This object is a specimen of the “Experiments” subclass of the “Scientific Result” class.

Navigation on the portal data is a process of transition from one information object to another according to the links specified between them.

The results of following the URL — attribute of the object and hyperlinks "111 — experimental data" and "Synthetic seismograms. Baikal2 "presented on Fig. 2 and Fig. 3. These links are used to transfer to the Information-computational System (ICS) "Vibrational sounding of the Earth"



Object properties

ExperimentsDB	
Result name	111 Experiment "Profile Baikal-Ulaanbaatar"
Result description	Field work on recording the wave field from a stationary 100-ton vibroseismic source located at the Babushkin test site, numerical modeling of the wave field on the Profile
URL	http://opg.sscc.ru/db/exp.php?ExpNum=111
Abbreviation	

Object communication

containedResult

OnlineResourse/ИнтернетРесурс

ICS "Active seismology"

containsDataIn

Experimental data (in ICS "Vibrosounding")

111- data from experiment No. 111 (visualization, analysis)

containsModellingResultIn

ScientificResult/НаучныйРезультат_Продукт

Synthetic seismograms of the Ulaanbaatar - Ulan-Ude profile (Baikal 3)

Synthetic seismograms of the Ulaanbaatar - Ulan-Ude profile (Baikal 1)

Synthetic seismograms of the Ulaanbaatar - Ulan-Ude profile (Baikal 2)

Wave field of the Ulan-Ude - Ulaanbaatar profile

hasAuthorResultOrganization

Organization

Buryat Branch of the Geophysical Service SB RAS

Geological Institute of the Siberian Branch of the RAS

Institute of Computational Mathematics and Mathematical Geophysics SB RAS (ICM&MG SB RAS)

Mongolia Research Center for Astronomy and Geophysics (RCAG)

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Kovalevsky (V.V.)

Odonbaatar S.

(Total: 7)

hasGoal

SubjectsOfResearch/ПредметИсследования | Language

Variations in vibroseismic field parameters

hasResultThemes

ScienceSection

Active seismology

Vibroseismic monitoring of earthquake-prone zones

isResult

ObjectOfResearch/ОбъектИсследования

Baikal Rift Zone (BRZ)

Ulan-Ude - Ulaanbaatar profile

usesResultMethod

ResearchMmethods&Tools/Методы и средства исследования

Methods of mathematical modelling

VibrationalSounding

UsesResultModel

Models

Velocity model of the Earth's crust for BRZ

Fig. 1. Knowledge Portal page containing the description of the experiment "111. Baikal–Ulan Bator profile".

Fig. 2 shows the ICS pages containing the description of the experiment (following the URL) and the page of the request for visualization and analysis of the seismograms of the recorder No. 1 at the distance from the source of 205 km.

The result of the spectral-time analysis of experimental seismograms and theoretical seismograms (click on the link "Theoretical seismograms. Baikal 2") are presented on Figure 3. The researcher has the opportunity to compare the amplitude and velocity characteristics of real and theoretical seismograms. The 205 km benchmark on the theoretical seismograms shows the time of the first head wave — 34.9 s, which is in good agreement with the maximum of the first wave train on the real seismogram.

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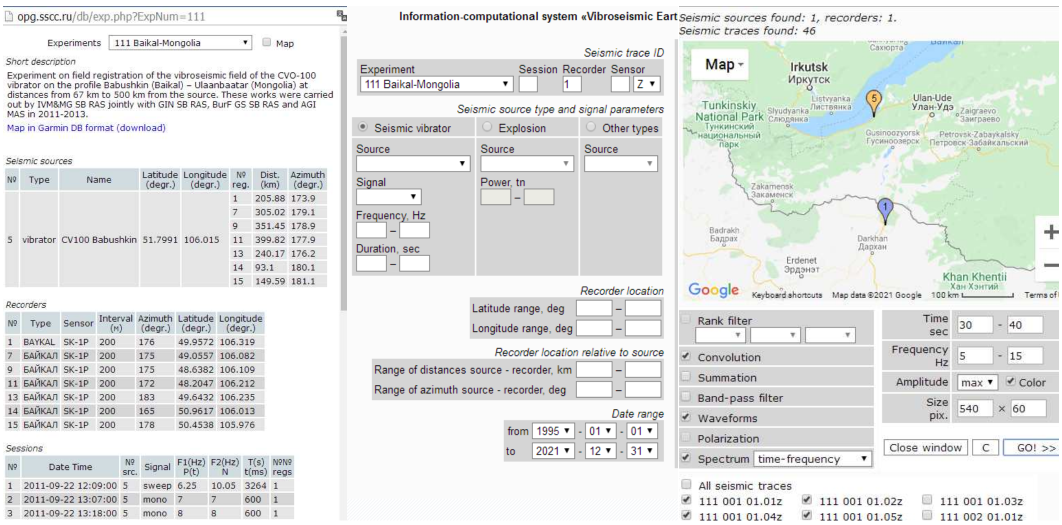

Fig. 2. The pages of ICS "Vibrational sounding of the Earth" with information about 111 Baikal-Mongolia experiment.

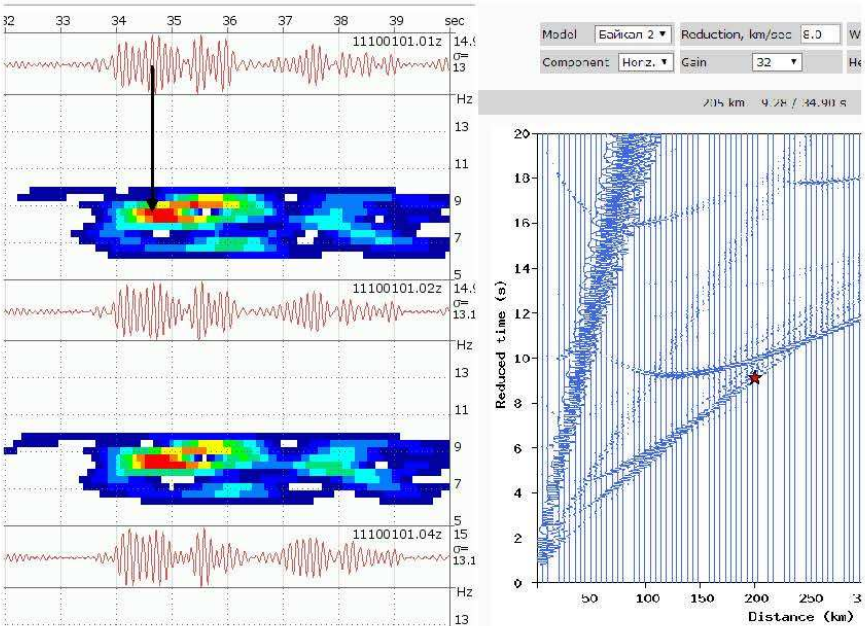

Fig. 3. The page of ICS "Vibrational sounding of the Earth" with results of spectral-time analysis of experimental seismograms and synthetic seismograms for Baikal2 experiment.

IV. Conclusions

This paper presents an Internet resource for supporting research in geophysics. The implemented ontological approach makes it possible one to use knowledge of the subject area to increase the efficiency of information provision. The main attention in the work is paid to the mechanisms of integration of heterogeneous information objects based on the domain ontology developed by the authors.

The Internet resource provides the user with access to databases and tools for data analysis of field and computational experiments, the results of numerical modeling of wave fields.

According to the authors, the developed Internet resource can be considered as an intellectual environment that allows researchers to visualize, analyze the results of experiments, and obtain the necessary personalized information to interpret the results and build new hypotheses.

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