The Framework of the Digital Environment for Analysing of Seismic Hazards of Lithosphere Blocks in Baikal-Mongolian Region

I.V. Bychkov[1], and G.M. Ruzhnikov[1,2] , V.V. Paramonov[1, 2, 3 [0000-0002-4662-3612]], A.A. Mikhailov[1[0000-0003-4057-4511]], R.K. Fedorov[1, 3], A.V. Klyuchevskii[4[0000-0002-1901-4985]], V.M. Dem'yanovich[4], and S. Demberel[5[0000-0002-1023-0075]]

[1] Matrosov Institute for System Dynamics and Control Theory, SB RAS, Irkutsk, Russia
[2] Irkutsk Scientific Center, SB RAS, Irkutsk, Russia
[3] Institute Mathematics, Economics and Informatics of Irkutsk State University, Irkutsk, Russia
[4] Institute of the Earth's Crust, SB RAS, Irkutsk, Russia
[5] Institute of Astronomy and Geophysics, Mongolian Academy, Ulaanbaatar, Mongolia
{bychkov, rugnikov, slv, mikhailov, fedorov}@icc.ru

Abstract. The Baikal-Mongolian region is the territory with high seismic activity for which issues of the dynamic interaction of mobile areas with the platform block at a neotectonic stage. Also, it is a pattern of a late Cainozoic fault formation are insufficiently studied. In this regard development of methods of zoning of seismic hazard of territories, with use of modern geoinformation, web technologies and service – the oriented paradigm is relevant. The information and analytical environment (IAE) of geoportal type allowing to integrate diverse databases of monitoring and to apply services to a solution of a number of problems of comparison and assessment of the dangerous geological processes happening in the region are developed for the analysis and assessment of dangerous geological processes. At the same time can be used, both local services, and distributed in an Internet network that allows application of the models, algorithms and databases developed by other researchers. The offered approach provides a possibility of loading of heterogeneous space and thematic data of IAE, including, contained in directories and bulletins of earthquakes of the Baikal-Mongolian region. IAE allows to carry out creation of various thematic cards and also to visually represent results of modelling of geological processes and zoning of seismic hazard.

Keywords: service-oriented paradigm, geoportal, geoinformation and web technologies, information-analytical environment, seismic hazard.

1 Introduction

A significant part of the Baikal-Mongolian region is located in the highly seismic areas of the Central Asian seismic belt. This territory is a subject to frequent and severe earthquakes. They are the primary cause of regional tectonic forces and influ-

ences. Fault formation and earthquakes are multi-scale properties of a dynamic system – a fault zone of shear. This is confirmed by the fact that the bulk of strong earthquakes are concentrated at the boundaries of lithosphere blocks (plates) in connection with large and mobile fault systems framing and separating these plates [1, 2]. Seismicity and strong earthquakes quite often occur far from the plate boundaries, especially in continental intraplate regions, in which there are fault structures inherited from previous tectonic stages. The main seismically active faults in the territory of the Baikal-Mongolian region form a dominant image and set the basic parameters of the map for general seismic zoning.

Different scientific institutions, departments of regional divisions of the Ministry of Emergencies of the Russian Federation and Mongolia, territorial authorities and departments processing monitoring of dangerous geological processes, earthquakes in the Baikal-Mongolian region. The specifics of monitoring are:

- distribution of seismic stations and their equipment;
- poor enough development of monitoring data exchange infrastructure in some areas of the region;
- large volumes and Spatio-temporal nature and different formats of data for monitoring;
- the localisation of systems for data storage and processing.

According to this, it is significant usage by modern information technologies to study the stress-strain state of the lithosphere, which forms the type and size of a potential seismic source. All these are the part of a comprehensive solution to the challenges of seismic safety in the Baikal-Mongolian region.

2 Information and analytical environment

The spatial nature of geological force necessitates the use of the conceptual framework of the spatial data infrastructure (SDI) of the integration type for their monitoring and analysis. This is based on [3]:

- requirements to standardisation and unification of software;
- implementation of the principles of organisation and creation of distributed information resources based on a service-oriented paradigm;
- free access and usage of spatial data (SD) and metadata through services according to the OGC specifications (WMS, WCS, WFS, CSW, KML, etc.);
- the usage of not only Web-services, SaaS services, services for searching and obtaining SD, but also on services for SD creation, analysis, and processing (cartographic Web-applications, as well as Web-applications with GIS functionality, etc.);
- creation of Geoportals and data storage and processing centres (DPC);
- continuity of existing spatial and thematic information resources.

The creation of IAE zoning of seismic hazard of large lithospheric blocks of the Baikal region and Mongolia includes:

– develop of a Geoportal and basic infrastructure components of IAE;
– the formation of subsystems for effectively filling the databases of thematic and spatial data of zoning;
– adaptation and implementation of original models of stress-strain state, seismicity, zoning, earthquake analysis of large lithospheric blocks;
– filling and updating the topical and spatial data of seismic zoning of the Baikal region and Mongolia (including the dynamics of the seismic process based on historical and instrumental monitoring);
– the formation of interconnected models of stress-strain state, seismicity, earthquake analysis, zoning, and seismic hazard prediction of large lithospheric blocks in the form of a complex of WPS services;
– the organisation in the IAE of a distributed "cloud" information and computing process with parallelisation elements to speed up the computing process and increase the multivariance of calculations.

The IAE of the geoportal-type is oriented to integrating different-format earthquake monitoring data obtained by seismic stations, various research groups, as well as the use of their processing services [3]. At the same time, both local services and distributed on the Internet may be used. This allows applying models, algorithms, and thematic databases developed by other researchers.

Using Web-based technologies allows us to expand the area of applying of the IAE without the need to install specialised software for each workplace.

The prototype of our IAE is built on the geoportal principles. For current stage of development, the environment contains a number of functions, such as data search; services and applications for centralised access to thematic and spatial data by their metadata; data visualisation, download (upload), transformation, remote call of services based on OGC standards.

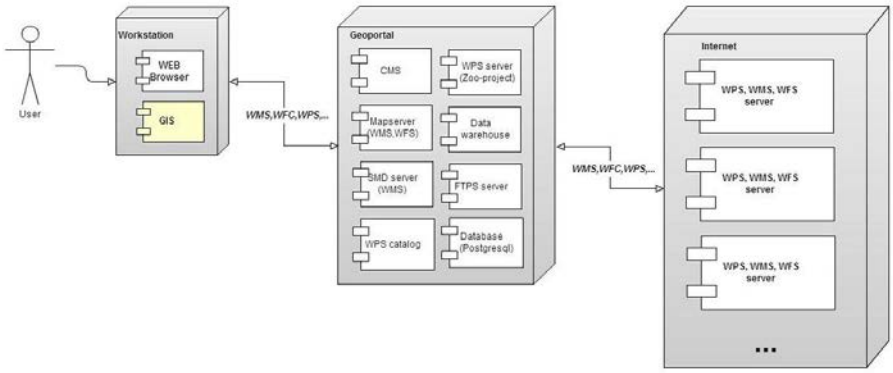

Fig. 1. Structure of IAE.

The structure of the IAE geoportal type is shown in Fig. 1 and includes the following components:

- The Service of Geodata Content Management System (CMS). It provides basic services of the Geoportal management presented in such as services as a file manager, access control for data and services, publishing and displaying datasheets, and launching geoprocessing methods. The CMS is based on the Drupal.
- Data storage system (DSS) – allows providing data storage. It is based on SAN ReadyStorage 3994, which guarantees storage, uninterrupted operation and high speed of reading / writing data.
- Server FTPS (File Transfer Protocol + SSL) is designed to provide access to the file system of storage. Simplifies the loading and unloading of large amounts of data. Managed by FTPS server using CMS.
- Metadata server – contains a catalogue of metadata and offers storage, processing of metadata using GeoNetwork.
- The PostgreSQL database management system (with the PostGIS extension for processing spatial data) is designed to store user datasets and service information of the geoportal. The PostGIS extension allows you to store spatial data and implements support for OGC standards.
- SMDServer – designed to visualize maps on the Internet. It provides a high-speed display of graphic and attributes information.
- WPS-server (created by the principles of Zoo-Project) – provides local and distributed on the Internet geo-processing of raster and vector data, organizes access to desktop GIS, geo-modelling packages and program interaction via the Web-interface.
- MapServer – an open-source server GIS, launched via the CGI (Common Gateway Interface), the environment for creating cartographic Web services, displaying user maps.

The use of IAE is focused on the accumulation, processing and visualisation of Spatio-temporal data of earthquake monitoring, regionalisation of the seismic hazard of the large lithospheric blocks of the Baikal –Mongolia region, as well as the identification of critical conditions and support for decision-making on safety issues.

Geoinformation functionality is used in IAE for processing monitoring data, unambiguous location, territorial sampling and creating thematic maps. It is the sequences of the backbone nature of spatial data and a digital model.

For interoperability providing, IAE uses the OGC (Open Geospatial Consortium, www.opengeospatial.org) Web-standards, which are modular applications that provide operations that are accessible over the network through their interfaces. Network interaction is based on standardised protocols that are independent of the platform, programming language, or the object model [3].

The integration of distributed databases of seismic stations in the Baikal-Mongolian region, including heterogeneous networks, is achieved through the use of service-oriented architecture (SOA), OGC standards, Web-technologies, standardisation of the browser software interface and the set of Web services. This allows moving them from local to distributed and "cloud computing" in which the information and computing resources of the IAE are provided to the user as Web-services. Transferring the storage and processing of monitoring data to remote servers makes it pos-

sible to simplify and reduce the costs of updating, servicing, and implements openness, scalability, the provision of common classifiers, the availability of data and processing services, etc.

In this case, a comprehensive analysis of earthquake monitoring data can be designed as a set (combination) of Web-services with standardised interfaces using protocols (SOAP, WSDL, etc.). Using SOAs extends the concept of a Web-service by providing an orchestration method (managing business processes and services) to combine small services into more general ones.

WPS services, created according to the Web Processing Service standard [4], play an important role in the information-analytical environment for seismic hazard zoning of the lithospheric blocks of Baikal and Mongolia. They present and define a universal interface to the geoprocessing Web service. The advantages of this standard are simplicity, the ability to provide metadata, supporting of long-term execution of services, etc. Different algorithms, models, GIS tools that operate on vector or raster data may be presented in the form of WPS services.

The data required by WPS services may be obtained via an Internet/Intranet network or accessible on a data server. WPS defines an interface that facilitates the publication of geospatial processes and the opening of clients associated with these processes.

The following services of IAE in the form of WPS were created:

- modeling of the environment of distribution of seismic signals and determination of dynamic parameters of the centres of earthquakes;
- estimating of recurrent intervals and the probability of strong earthquakes in the region;
- - data processing of radar survey of SRMT;
- - data transformation and converting;
- - primary statistical processing;
- - calculation of density of point and linear objects in cells of a regular grid;
- - decoding of set of GRID data support vector machine;
- - creations of the qualifier of the GRID set;
- - decoding of set of GRID data on the basis of the qualifier;
- - approximations of point data on the basis of a method of the closest neighbours.

Developed WPS services are based on the use of open-source libraries, which allows them to be adapted in interdisciplinary scientific research and modelling of geological processes.

The environment allows analyse the seismotectonic situation in the territories of large lithospheric blocks of Baikal and Mongolia and support decision-making on prevention adverse natural processes. This is possible thanking the using of modern standards for software interaction, application of database models, spatial data analysis tools, processing services for large volumes of spatial and heterogeneous thematic monitoring data.

2.1 The environment data upload service

Let us consider some of crated IEA services more in detail. One of them is the service for data upload and normalisation.

The uploading to IAE user-created data should be presented in files of Excel or CSV formats Before data uploading, the meta-information that describes these data should be added. It presents the description of table fields' structure and type of their data. This additional information allows us to integrate data into the IEA database. The user-created data needed to be clean [5]. Data cleanse operations consist of many aspects such as detection and correction of spelling errors, missing data, incorrect values, and logical inconsistencies. One of the important tasks of data cleansing is to associate source values (natural language strings) with target thesauruses and qualifiers. Cleaned data upload into the database. The general schema of data uploading is presented on fig. 2.

A special file manager that allows to perform all basic operations with the file system on the server through the user's browser, as well as download and upload documents from the user's computer has been developed. Operations are providing by HTTPS or FTPS protocols.

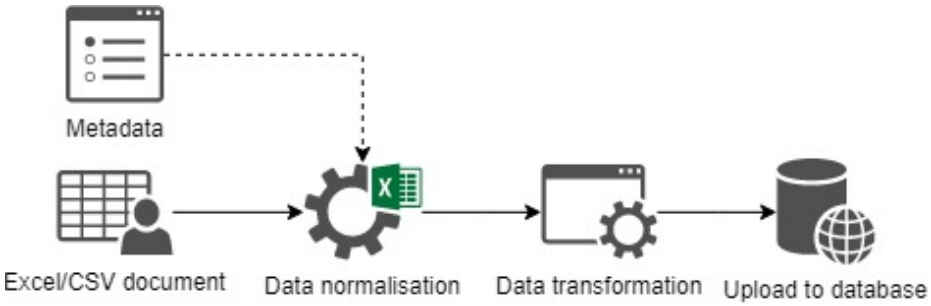

Fig. 2. Data uploading scheme.

Samples of data were uploaded into the IAE database. They were cleaned and normalised, the set of the data is planned to be used for conducting seismotectonic and seismological studies, including for detailed regionalization:

- Data of the Baikal branch Federal Research Center "Unified Geophysical Service of the Russian Academy of Sciences" (http://seis-bykl.ru/) that contains the information about earthquakes that occurred during the period from 01/01/1994 to 01/01/2016 in the territory of 48.00-60.00° N, 99.00-122.00° East, energy class K_P from 8.6 to 17.5. The data contains the date and time of the earthquake, coordinates, energy class and possible comments. The loading of relevant data for the current year, as well as from 1994 to 2018, was implemented with the aim of filling the database through the analysis of the HTML page.
- Data from the Institute of Astronomy and Geophysics of the Mongolian Academy of Sciences on earthquakes that occurred during the period from 01/01/1994 to 01/01/2018. Partially adapted software for seismic hazard assessment using

ODPSHA (Open Deterministic and Probabilistic Seismic Hazard Assessment) calculation and probabilistic methods. The method is based on the analysis of general seismicity, the recurrence time of strong earthquakes on active faults, the decrement of the seismic wave attenuation.

- Data of historical and instrumental monitoring of the Institute of the Earth's Crust of the SB RAS on earthquakes in the Baikal region from 1725 to 2017.
- Data on the annual energy released as a result of seismotectonic processes from 1960 to 1986. The initial data were presented as poorly structured information in Excel format documents. They were extracted, normalized and presented in the form of relational tables. These data are an extension of the information provided by the Baikal branch of the Federal Research Center "Unified Geophysical Service of the Russian Academy of Sciences".
- Radon emission data.
- Data of numerical parameters describing the results of particle size analysis of soils of the most representative samples of loose sediments. They present an interest for research of planning landslide deformation of territories.
- Results of a chemical analysis of hydrochloric acid extraction of soils of the most representative samples of loose sediments.
- Data on the landslide section profile (Kharantsy settlement for the period 2007-2017 yy).

2.2 Data entry and editing service

The interface of the service for tables input and editing is formed. It is used the structural specifications of the data (metadata) that contain information about the table, attributes and their properties. Functions of data entry and editing are carried out in both in table presentation and in the web-interface form.

The user interface generation module sequentially bypasses all the attributes specified in the specification. Each attribute is used for generation of an appropriate input field control elements on the form and in the table cell. Data spatial attributes allow creating layers for displaying data on the thematic map. The operations of sorting and data filtering are accessible for all attributes of created tables.

The use of CMS control elements allows creating a flexible user interface for processing relational tables with some set of attributes without programming. For example, by choosing a control, it is possible to define complex interactions with the map, reference tables, etc. Currently, more than twenty different controls have been developed that allow working with standard data types: number, string, date, Boolean values, etc.

2.3 Service of dynamic parameters of earthquake sources

To calculate the dynamic parameters of earthquakes a WPS service developed. They are based on the calculation method, proposed in [6]. The (1-4) are used for the calculation:

$$Mo=4\pi\rho RVs^3\Phi o/\ \Psi\theta\varphi, \quad (1)$$

$$Ro=2.34Vs/\ 2\pi fo, \quad (2)$$

$$\Delta\sigma= 7Mo\ /16R^3, \quad (3)$$

$$D =Mo\ /\mu S, \quad (4)$$

where Mo is the seismic moment, days cm; Ro is the dislocation radius in km; $\Delta\sigma$ is the average voltage drop in the source in bar; D is the average displacement along the gap in mm; ρ *=2.7 g/cm3* is the density of the medium; Vs = 3.58 km/s is the propagation velocity of bulk shear waves; R is the hypocentric distance in km; $\Psi\theta\varphi = 0.6$ is the value of the radiation directivity function from the source; $\mu = 3\times10^{11}$ days/cm^2 is the shear modulus; S is the gap area in km^2.

The advantage of the technique is that the determination of dynamic parameters is performed in one way without subjective estimates of the level of the amplitude spectrum and the angular frequency of each earthquake. Such a simplified estimation of dynamic parameters makes it possible to use the huge seismological material accumulated in the Baikal region during the registration of earthquakes by seismic stations with galvanometric recording.

The created WPS-service of IAE is implemented in C++ as a dynamic link library (DLL). As input parameters, the service accepts an earthquake bulletin file, which contains the earthquake parameters, such as date, latitude, longitude. In addition, the file contains parameters obtained from various registration stations for this earthquake. Parameters for models are located directly on the server and are not available for change.

3 Conclusion

Developing of the service-oriented information-analytical environment (IAE) for seismic hazard zoning of large lithospheric blocks of Baikal and Mongolia with spatial analysis functions allows providing monitoring and comprehensive analysis of the seismotectonic environment and decision-making to prevent and minimize risks from adverse natural processes. The IAE helps to accumulate heterogeneous data into a single database and attract different services (both local and distributed in the Internet) for data analyses.

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