Geological information database integration into a geographic information modeling system

A S Kanukov*,1, P G Ivanov2

1Geophysical Institute of the Vladikavkaz Scientific Center of the Russian Academy of Sciences, 93a,Markova str., Vladikavkaz, 362002, Russia
2Geological Institute "Str. Dimitrov", Bulgarian Academy of Sciences, Acad. G. Bonchev st. bl.24, 1113 Sofia Bulgaria

Abstract. The article is devoted to the geological information database integration into a geoinformation modeling system. With the high technologies’ development, various geographic information systems designed for collecting, storing, analyzing, and graphically visualizing spatial data and the related information about the objects represented in GIS have become widespread. A map of the engineering-geological zoning of the Vladikavkaz city territory has been created at the Geophysical Institute, covering the issues of the geological structure, hydrogeological conditions, lithology, morphology, tectonics and the distribution of various types of soils in the territory under consideration. There are areas on the territory characterized by different depths of pebbles or thicknesses of clay and loam on pebbles, which is the main parameter that determines the seismicity category according to Building Codes and Regulations-II-7-81*. Based on the physical and mechanical properties’ analysis, the reliable differentiation of soil groups with various determining indicators characterizing the soils’ category by their seismic properties has been carried out. This information is collected in a database of geological information generated in the form of a shape file with spatial reference of each well. The developed database is used as a basis in the geographic information modeling task. Based on open source software, the integration of the geological information database in the Vladikavkaz city into the geographic information modeling system has been performed.

Introduction
Assessment of the seismic hazard in an urbanized area, based on modern scientific approaches and methods, is an essential component in determining the expected level of seismic risk in implementing a scenario-specific seismic impact for a given region and developing the specific risk management measures to reduce the territory vulnerability and ensure the safety of its population and further development.

The manifestation of a strong and destructive earthquake, in turn, is largely determined by the soil conditions of the territory [1]. In this regard, special attention is paid to the appropriate soil distribution schemes’ creation for various types of soil in a given urbanized territory [2-7]. The detailed schemes of geological zoning of the settlements’ territories in the Republic of North Ossetia-Alania were the basis of seismic microzoning [8-9]. In this case, a detailed geological zoning of soils...
for engineering and geological surveys in an urbanized area is carried out using modern geophysical methods [10-12]. A special place in the study and subsequent differentiation of soils with the allocation of their features and characteristics is occupied by the geoinformation modeling data [13-15].

Geoinformation modeling is currently still a relatively young area of scientific research, which covers an extensive range of questions on the creation and use of geoinformation systems (GIS systems) about objects and their characteristics, as well as on the mathematical methods and algorithms’ application in these systems. GIS systems include DBMS (database management systems), editors of graphics presented in vector or raster format, various analytical tools, which allows them to be used in cartography, geology, geophysics, ecology and many other areas. Geoinformation modeling is widely used in geo-ecological [16-17], geophysical [18] and other [19] studies.

As a result of a number of studies, the Geophysical Institute created a map of the engineering and geological zoning of the Vladikavkaz city [8], covering the issues of its geological structure, hydrogeological conditions, lithology, morphology, tectonics, and the distribution of various types of soils in the territory under consideration. The areas of different pebble bedding depths and different thicknesses of clay and loamy cover on pebbles were identified on the territory, which are the main indicators that determine the seismicity category according to Building Codes and Regulations-II-7-81*.

Based on the soils’ physical and mechanical properties analysis, the groups were differentiated according to their seismic properties (Building Codes and Regulations-7-II-81*).

The aim of the work was to compile a map of seismic microzoning based on the detailed geological zoning schemes.

A GIS project “Database of geological information of the Vladikavkaz city territory” was created. The situational basis in the contours form of quarters, streets, the position of the Terek River and anthropogenic load is obtained from the existing specialized bases.

Three thematic maps created:
- well-location map;
- depth map and pebble roof depths;
- map of engineering and geological zoning.

Thematic maps are created with related databases. There is only one layer of “mine workings” with fields on the well-location map:
- production type (well, trench, pit, hole);
- index (production number and type index), the field is rendered for signature on the card;
- conduit number.

The map of engineering-geological zoning also carries the information about the conduit. In addition, the following information is provided:
- slopes with steepness of more than 15 degrees (polygon layer, without attributive data);
- soil categories by seismic properties in accordance with existing Building Codes and Regulations requirements II-7-81*.

The subsequent development prospects of the created geocoded databases come down to the spatial analysis of attribute information. Based on it, it is possible:
- to create the repeating fields with the functions of refinement and information updating based on new received data (i.e., detailing);
- creating correction sheet;
- overlay with information about the hazardous industrial facilities;
- overlay of water horizons and lenses roof depths;
- solving other spatial problems.

The soils’ description is given for all wells in the GIS project (Table 1). This information is collected in a database of geological information generated in the form of a shape file with spatial reference of each well.
Due to the fact that the developed database is used as a basis in the geoinformation modeling task, it had to be prepared beforehand in order to be able to work in the geoinformation system. In this regard, it should be noted that the materials in the geographic information system should be designed in the form of databases [14]. At the same time, any object put on the map should be linked to the materials related to it. Thus, it is necessary to combine databases and cartographic materials with spatial relationships. In this regard, the database management system should provide support for both text and graphical databases, and spatial. For example, PostGIS can serve as such a subsystem.

Table 1. Description of mining soils (example of database content)

| Well numbers | Depth, m | Description of soils | Absolute mark of the mouth, m | Depth of pebbles, m |
|--------------|----------|----------------------|------------------------------|-------------------|
| 4E2          | 0 0.1    | Bulk layer           | 669                          | 2.4               |
|              | 0.1 0.3  | Pebbles layer        |                              |                   |
|              | 0.3 2.4  | Brownish-brown loamy refractory humus with admixture of gravel and pebbles up to 10% | 669 | 2.4 |
| 4E2          | 2.4 12.0 | Pebbles              |                              |                   |

PostGIS is an extension of the free object relational database management system, which is designed to store the additional geographic attributes in the database - geometry. PostGIS supports the OGC (OpenGeospatialConsortium) standard and has been released since 2001 by Refractions Research, competing with many commercial projects, while remaining a free software product that is an open source. The main advantage of PostGIS is the ability to use the SQL language along with spatial functions and operators. At the same time, a fairly active development of the PostGIS program is observed as PostgreSQL and the OpenSourceGeospatialFoundation project are developing, collecting the best of them. For example, due to the development of PostgreSQL in PostGIS, it became possible to use such innovations as bitmap and Gist indexes.

Due to the alliance with OpenSourceGeospatialFoundation [14], PostGIS has now the ability to support such programs as GEOS, Proj4, and JTS. In 2001, only one application - MapServer was able to display the data stored in PostGIS. To date, almost all applications for working with cartographic data, both paid and distributed on a non-commercial basis, allow working with this data. Among the latest software are GRASS, QGIS, MapServer, uDig, GeoServer, GDAL / OGR, SharpMap, gvSIG, FeatureServer.

PostGIS provides the full functionality of spatial operations (respectively, to OGC), which make it possible to implement any spatial operations with geodata. Choosing PostgreSQL + PostGIS gives a possibility to get the most fully functional system that will support the operations with spatial data, being a very powerful system when working with a database.

Due to this service, which stores geodata in a database and gives an opportunity to filter and select the necessary data using the standard SQL queries, it is possible search for the necessary objects, both by coordinates and by using other information stored in the attributes of each record.

Using such blocks makes it possible to store the already created GIS objects, create the new ones, and also perform any spatial operations with them.

GeoServer was used to visualize the contents of the spatial database. GeoServer is a web server that provides standard clients, such as web browsers and various GIS, with access to various maps and data that can be stored in almost any format, while the user does not need special knowledge about geographical data. In the simplest case, all that is required is a web browser that displays the maps in the exactly required form.
GeoServer represents a reference implementation of OGC standards: WFS (WebFeatureService), WCS (WebCoverageService) and is the main component GeospatialWeb.

It should also be noted that its distinguishing feature from a number of others (MapServer or FeatureServer) is a graphical system for managing settings and data description for the projects implemented in GeoServer. This system is implemented as a web service, with the interactive creation and modification of cartographic materials in the system.

In addition, GeoServer uses the StyledLayerDescriptor (SLD) description language to set the styles. Initially, it was created to work with WMS services [14]. It is possible to prepare a style file in the SLD language and transfer it to a third-party WMS server, and at the same time get a map designed in accordance with the user’s requirements.

When solving such problems, it is also necessary to take into account the important fact that the database should be protected from unauthorized access. To do this, the geographic information system should have means for authenticating the users. Basic authorization is implemented in GeoServer, but is vulnerable to the authorization data interception attacks, making possible to view maps without registering on a web service. The way out of this situation is the use of the so-called https binding, in which all data between the client and server is encrypted.

Using this method, support for the https protocol can be introduced, even if the source software does not support it, which may occur in the case of a ready-made system. For these purposes, the pound program is suitable, which “listens” to a specific port and works through it using the secure https protocol. The data arriving at this port is decrypted and redirected to the internal port, which the program “listens to”, and into which the protocol support https is entered.

For the pound service to work, a certificate should be obtained and installed in the system. The certificate consists of two keys - public and private. The public key is used to encrypt traffic from the client to the server in a secure connection, the private key is used to decrypt the encrypted traffic received from the client on the server. After generating the public and private keys, based on the public key, a certificate request is generated to the Certification Authority (CA), in response to which the CA sends a signed certificate. When signing, the CA checks the client, which allows him to guarantee that the certificate holder is who he claims to be. Each signed certificate has a validity period and a fee is usually charged for creating / renewing a signature.

However, it is possible to create such a certificate without contacting the Certification Authority. They can be created for the stations that run on Unix / Linux, which is also an advantage of this system. Such certificates are signed by themselves and therefore are called self-signed. If this certificate is not verified in any other way, then the use of this protocol can be subjected to a man-in-the-middle attack, that is, a man-in-the-middle. Its essence is that the intruders can connect to the channel through which a secure connection is established, and intercept all the requests that go between the server and the client. In this case, the intruder is presented to the client as a server, and to the server as a client. Since it is possible to confirm the fact that the server is what it claims to be only with a certificate issued by the CA, such attacks are easily feasible for the self-signed certificates. At the same time, the direct transmission of a self-signed certificate through a closed channel and installing it in the system as a trust that allows avoiding such attacks.

To display maps in an information system, a spatial data visualization system is required. The main requirement for this system is the support of layers provided by WMS (and WFS) servers, such as Mapserver, ArcIMS or Geoserver, and the data from Google map services.

As an example of a finished product, the OpenLayers library can be considered as the most functional and open of all the existing systems.

Using the OpenLayers library makes it possible to quickly create a web-service for viewing the cartographic materials, which can be presented in various formats and can be located on different servers. Due to OpenLayers, the developer has the opportunity to create his own map, the source materials for which can be stored on such servers as Mapserver, ArcIMS or Geoserver, as well as the data provided by Google services.

It should be noted that OpenLayers is a free software product, open source.
The following features are implemented in the OpenLayers system:

- Adding a navigation panel to the map that contains controls such as map navigation buttons and zooming.
- Moving the map with the help of the “mouse”;
- Changing the map scale by scrolling the “mouse” wheel;
- Getting coordinates under the “mouse” pointer;
- Conclusion of the separate layers’ visibility switches to the control panel;
- Selecting an object on the map and receiving all the related information;
- Changing the transparency of any of the layers presented on the map;
- Editing elements on the map by the user.

Thus, the open source software use made it possible to integrate the database of geological and geophysical (engineering-geological, hydrogeological, geomorphological) information on the Vladikavkaz city territory into a special geographic information system with significant functionality.

Summary

- As a result of a number of studies, a map of engineering-geological zoning of the Vladikavkaz city territory has been created, covering the issues of the geological structure, hydrogeological conditions, lithology, morphology, tectonics, the distribution of various types of soils in the territory under consideration.
- On the Vladikavkaz city territory, the plots with different depths of pebbles and thickness of clay and loam on pebbles were identified, which are the main indicators that determine the soils’ seismicity category by the Building Codes and Regulations requirements-II-7-81*.
- Based on the physical and mechanical properties’ analysis, including (if necessary), with the help of their additional study by geophysical methods, differentiation of soil groups by the seismic properties was carried out.
- A GIS project “Database of geological information of the territory of the city of Vladikavkaz” has been created, including the information on wells in the city with a detailed soil description.
- Based on the open source software, the integration of a geological information database in the Vladikavkaz city into a geographic information modeling system has been performed.

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