Main theses of the PhD dissertation

Doctoral School of Earth Sciences

Managing and processing the geospatial data of Bátaapáti National Radioactive Waste Repository in a spatial database

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1. Introduction

Low and intermediate level radioactive waste from Paks Nuclear Power Plant was planned to be disposed of in a geological repository established with mining methods. In considering potential host rocks for the repository, the evolutionary history of the host rock and the geological, tectonic, and rock mechanical properties influencing the host's primary and secondary isolation potential had to be analysed thoroughly. Besides that, the information needed to assess long-term stability had to be collected. The repository for low and intermediate level radioactive waste and the corresponding facility was designated to be located in Eastern-Mecsek, in Bátaapáti.

Bátaapáti and its wider surroundings became a particularly important research area because of all these aspects, in which multiple scientific disciplines worked collectively to assess suitability. As tunnelling progressed, geological, tectonic, and geotechnical properties were documented too. During the mining activities, geodesical cross-sections and accurate 3D photogrammetric models were made of each heading.

A significant amount of geometric and attribute data was collected during the research, design, and construction phases of the National Radioactive Waste Repository (NRWR). These were handled separately in several files.

To be able to store, analyse and preserve this significant amount of geometric and attribute data in a suitable environment in the long term, the need to build a spatial database that provides the opportunity to store and connect extensive earth science data in a unified system for filtering and analysis.

2. Purpose of study

The purpose of this study is to give an information system design plan and the steps demonstrating implementation for storing, handling and visualizing spatial data, mainly based on open-source technology. Through the example of NRWR, it can be demonstrated how to build a unique geographic information system (GIS) that can be operated in the long term, which can also be useful for other earth science fields or projects. Another goal is that to illustrate the practicality of the developed geoinformation system, a mapping and evaluation from a geotechnical point of view have to be carried out.

The GIS system must meet the following conditions:

- A stable, well-documented spatial database management system should operate on the server side.
- The webGIS application connected to the spatial database has to provide the possibility of using Structured Query Language (SQL) for filtering.
- To ensure the safety of spatial data an intermediary channel must be established, one which supports the web-based connections which are standardised by Open Geospatial Consortium (OGC).
- To implement the map view of the webGIS application, a JavaScript library with a wide range of features must be selected.
- A JavaScript library used for visualizing 3D models in a web environment, which can display the results of photogrammetric surveys (e.g., point cloud, textured 3D model) has to be integrated.
- Basic measurement tools in both contexts of the webGIS application (map and 3D) must be available.
- Development of special analysis tools in both views of the webGIS: comparison of layers, interpolation, geometry edition.
- Integration of system components without compatibility problems.

The aim of the comprehensive study of the topic was to answer the following research questions:

Q1: How to create an earth science database that handles data from a variety of fields and formats?

Q2: What is the appropriate way to create a geospatial information system that can serve earth science data to different users in the long term?

Q3: In a webGIS software based on open source technologies, how can earth science data stored in a spatial database be filtered and sorted?

Q4: How can web-based function for modelling geological surfaces be implemented?

Q5: How can errors arising from the position determination of a seismoacoustic measurement system be filtered with a GIS system?

Q6: To what extent do the seismo-acoustic data and the geoinformation analysis of tunnelling correlate with the excavation damaged/ disturbed zone definitions affected by mining and how does this affect the stability of the chambers?

3. Research methods

During the planning and implementation of the geoinformation system presented in the doctoral study, geoinformation modelling was used: theoretical model, logical model, physical model. This approach was used in the context of an information system plan, the building blocks of which were the following:

- Modular design and the presentation of the communication between modules and processes.
- Architecture: the presentation of selected technologies and system components with their dependencies.
- Delineation of the persistence layer: data types and data models.
- Description and presentation of the interfaces in connection with the server-side. The components, dependencies, and features in the case of custom software.
- Description of security and access levels.
- Features supporting operation: logging, monitoring, troubleshooting.

In the course of the work, many different software and programming languages had to be used. For preparing and processing the data Microsoft Excel, ShapeMetriX 3D, ArcGIS for Desktop 10.5, QGIS 2.14.12 and 3.30, CloudCompare 2.6.1, Blender 2.79, Blend4Web CE 18.05.0 software was used. For data preparation and data processing, Python 2.7.12 and NumPy 1.9.3 versions were used.

For instructing the database SQL, and for programming the server-side PHP Hypertext Preprocessor was used. The web-based geoinformation software was built with HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript programming language.

The selected technologies which make up the geoinformation system were subject to detailed examination: servers, database management systems, web-based GIS JavaScript library, and web-based 3D JavaScript library.

4. Conclusion

During the development of the doctoral study, all research questions have been answered. By evaluating the results, the following theses could be established:

1. *To be able to load the spatial data into a database, with regard to the condition of geometric and attribute data, conversion into the common formats of Geographic Information Systems is indispensable. In many cases, these conversions require data preparation. In order to organize the various sources of data into a database, it is necessary to create a data processing and upload plan. The comprehensive plan I prepared can be a solution when creating many earth science related databases.*

2. *Due to the long-term data access, it is definitely advisable to choose the most common formats and data types, since these data can be easily converted. The GIS system must serve several users with different knowledge levels: developers due to continuous maintenance and new developments, users with write privilege who can modify and expand the database with desktop GIS programs, as well as those with reading privilege who access the data in a map and 3D view in an easy-to-use webGIS.*

3. *In order to filter earth science data organized in a database via webGIS software, it is necessary to develop an SQL query window. The query window requests data from the GeoServer via a Web Feature Service SQL View connection, which sorts the data tables of the spatial database. The filtered geometric and attribute data can also be displayed on the map and 3D model space of the web interface.*

4. *Web-based kriging interpolation is needed to model geological surfaces. For the 3D map of the results of the interpolation, breaking with the traditional raster output is needed since it is difficult to handle a raster in 3D on the web and it does not allow for further manual modification or editing. The predicted values of the geostatistical calculation can be retrieved from the result matrix and can be organized into a spatial grid,*

displayed as a 3D mesh geometry. This mesh is suitable for manual editing by querying the vertices and changing their spatial position.

5. *Based on the seismoacoustic emission signal sources and the 3D models of the tunnel system, it is possible to determine what the tunnel system looked like in a given time section. Acoustic emission signals falling into tunnel models can be considered to be in the wrong position. Direction vectors can be generated from the point sources detected in the wrong position and from the nearest point of the tunnel, whose inclination angle can be determined. Based on the tilt angles, the directionality of the faults can be demonstrated, on the basis of which the allocation of the sensors of the seismo-acoustic measurement network can be improved.*

6. *By the examination of the 3D distance between the acoustic emission points and the tunnels, it can be noted that 31% of the registered signals are located in the 4-meter zone around the storage chambers and 56% in the 7-meter zone. These values correlate well with the excavation damaged/disturbed zones defined by numerical modelling carried out during previous research. In the 7-meter rock belt, the most intense seismoacoustic signals can be seen at the end of the chambers I-K2 and I-K3 and between the side walls of the 4 chambers. Due to the fracture system close to the ends of the chambers, the rock may be weaker here, while the higher values are caused by the stresses changed by the cavities between the adjacent side walls. In the future, these areas must be monitored in order to detect any geometric distortions of the cut in time.*

List of publications in connection with this topic

Papers published in journals

Szujó, G., Biber, Z., Gál, V., Szabó, B. (2023). *MaGISter-mine: A 2D and 3D web application in the service of mining industry,* International Journal of Applied Earth Observations and Geoinformation, https://doi.org/10.1016/j.jag.2022.103167 11 p. **Q1**

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Somodi, G., Krupa, Á., Kovács, L., **Szujó, G.** (2018). *Reviewing length, density and orientation data of fractures in a granitic rock mass* - Geomechanics and Geodynamics of Rock Masses - Proceedings of the 2018 European Rock Mechanics Symposium, Saint-Petersburg Mining University, Oroszország, pp. 439-443.