WebGL based visualisation and analysis of stratigraphic data for the purposes of the mining industry

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Abstract
In recent years the combination of databases, data and internet technologies has greatly enhanced the functionality of many systems based on spatial data, and facilitated the dissemination of such information. In this paper, we propose a web-based data visualisation and analysis system for stratigraphic data from a Polish mine, with visualisation and analysis tools which can be accessed via the Internet. WWW technologies such as active web pages and WebGL technology provide a user-friendly interface for browsing, plotting, comparing, and downloading information of interest, without the need for dedicated mining industry software.

Keywords: WebGL, databases, 3D visualisation

1 Introduction

The mining production process is unique to each mine. Repeatable production conditions are rare compared to other industries. The geology of deposits, which is always recognized with established accuracy, is not the only factor of uncertainty and risk. Mining in general, and in particular underground mining, is characterized by complex mining technology, poor and limited visibility, difficult working conditions and frequent geological incidents. Therefore, an inevitable trend in the mining industry is the introduction of innovative modern technologies in order to counteract these problems.

There are several projects (Kęsek, 2010; Sarkka, 2008; Magda, Woźny, Głodzik, & Jasiewicz, 2008; Brzychczy & Mieszaniec, 2011) related to the issue of the so-called Intelligent Mine, both worldwide and in Poland. These projects explore the use of advanced information systems, both in underground mining and in quarrying. The basic elements of such systems include:

- Databases for design and production planning, including geological, mining, technical and financial data,
- System modelling, including simulation and optimization of the proposed mining works,
- Systems for visualizing mining in time and space, with projections of the figures and parameters observed.

In practice, the implementation of advanced software is an extremely difficult process which is often limited by high purchase and implementation costs, the resistance of workers to new solutions, the belief that the current system works and there is no need for change, the need to purchase new hardware, and the complicated structure of new solutions. This situation often leads to intermediate solutions within the process of mine computerization. Such solutions involve the use of various types of methods and IT tools at different stages of the design and monitoring of the mining process. These solutions are used, for example, while collecting, analyzing and carrying out data visualization. Databases related to information on deposits are particularly important here since they store a number of parameters assigned to coordinates in a dimensional structure. Available spatial database systems offer the required storage capacity for this type of information (Lisowski, Krawczyk, & Porzycka-Strzelczyk, 2014; Płuciennik & Płuciennik, 2014; Kulesza & Wójcik, 2014). In addition, databases should store information about mine workings and other facilities which should be included in the model, and also keep information about previous mining activities.

The visualization of collected data seems to be an important element of software in this field. There are, of course, various types of specialized software used in the mining industry at various stages of mine design, data analysis and visualization (Sypniewski, 2011).

There are several specialized systems such as Surpac, MineSched, Datamine Studio, Vulcan, MineScape and RockWare that can perform the wide range of tasks necessary in the mining industry. These systems are used not only for collecting data both from borehole investigations and underground mining, but also in geological model construction processes. They can also conduct basic statistical analysis in order to choose the best method of interpolation used in generating maps and geological cross-sections. The results obtained by the aforementioned software are largely similar, however the processing stages and algorithms used may be different. Computer programs such as Surfer, AutoCAD, ArcGIS and Statistica are also used for visualization and basic data analysis. However, the use of these systems often involves high purchase costs and the need for qualified personnel.

This solution presented in this paper focuses on using modern technologies with free software licenses so as to be easily modifiable and easily accessible to a wide range of users, including administrators and clients. Another advantage of the proposed solution is the on-line access which can be used for monitoring and making changes to the analyzed area. Furthermore, the presented system can be adapted and even expanded to the individual requirements of any given mine.

This paper presents the preliminary version of the STRATOS system for collecting, analyzing and visualizing mine data. The current version of the database holds 3D information relating to the geological model of the analyzed mine, focusing mainly on the 3D visualization of the collected data set. For this purpose, the WebGL library has been applied. This library is widely used in the fields of visualization, 3D modelling and computer games. A multiplayer game website is shown in the paper (Bijin & Zhiqi, 2011) using the WebGL and WebSockets libraries for communication. Another potential use of WebGL is 3D modelling, for example the Tinkercad project, (Tinkercad, n.d.) which allows users to draw Tinkercad 3D models inside a web browser and send them to any printer. The third way to use WebGL is for the visualization of complex data that requires 3D presentation. One such project is described in the article (Congote, 2011), which uses WebGL for imaging medical applications. Another example is the project (Lecocq, 2010) which demonstrates the ability to quickly view mathematical premises in a browser. In (Krooks, et al., 2014) a novel concept for processing and analyzing geospatial data sets was introduced, and WebGL technology was applied for visualization the resulting 3D environmental models.

WebGL performance is very promising when compared to Flash (Zvonkov, 2012). However, poor support on the side of the browser is currently still a big problem when the application needs to be available to multiple users. Hopefully, wider use of the WebGL library will improve this situation.
2 Description of the data model

This paper presents the use of a database for developing a 3D geological model which can be obtained only with the use of stratigraphic profiles or with data obtained during different measurements such as seismic, radar or electrical surveys. The precision of the model is dependent on the quantity of data that is available. The geological model presented in this paper was created on the basis of stratigraphic profiles obtained from lithological and petrographic surveys. The data used for the model comes from the actual data used in a Polish mine.

The data obtained from the stratigraphic wells include geological layers going down to a depth of a maximum average of 1000 m below ground level. These wells penetrate geological layers beginning in the Quaternary and finishing in the Paleozoic layers (Fig. 1a). The subsurface layers were constructed by utilising interpolation techniques (Fig 1b).

![Figure 1: Geological layers in the data](image)

3 Implementation of the STRAROS system

3.1 System Architecture

The presented system for gathering, analysis, and visualisation has a typical client-server architecture. Data is stored on a server to which clients have access from remote stations. Fig. 2 shows a diagram of the STRATOS system. The program is written in Microsoft Visual Studio 2010, using ASP .NET Framework in C#. The MVC design pattern was used to organise the structure of the application. The Telerik Extensions are responsible for the presentation layer, allowing the creation of tables, windows and charts, and simplifying the building of web applications. The WebGL Library was used...
to create the 3D visualisations and provide access to the 3D programming interface in a web browser. In order to facilitate the manipulation of HTML elements the JQuery library was used as it allows complicated scripts to be replaced with equivalent methods from its library. The free Express-C version of the IBM DB2 relational data server is responsible for storage of data. Access to data is achieved with LINQ, which is part of .NET technology and enables a SQL-like syntax. For object-relational mapping the Fluent nHibernate library was used.

![Diagram of STRATOS system](image)

**Figure 2: STRATOS system diagram**

### 3.2 Database Scheme

Databases and computer systems based on databases have become an indispensable part of almost every area of human activity. They are used, for example, in the design process of modern scientific experiments (Gaj & Kwiecień, 2009; Balış, et al., 2011; Chuchro, Lupa, Pięta, Piórkowski, & Leśniak, 2015; Pięta, Chuchro, Lupa, Piórkowski, & Leśniak, 2014) and for collecting and analysing results and measurements from experiments. The database structure and algorithms used to optimise database operations are highly dependent on the specific issues of the scientific or experimental research for which they are designed (Kowalski & Hareźlak, 2011; Kulesza & Wójcik, 2014).

The data obtained from the stratigraphic measurements was stored using an IBM DB2 database management system, with the lithological data mapped into a single table. The attributes of the table contained a measurement identifier representing the source of the geological data, the source’s coordinates, and the value where a particular geological layer level was measured (Fig. 3).

![Lithological data table](image)

**Figure 3. Lithological data table**
The only group of data in the database is geological, represented by a single table scheme. This kind of a database construction allows easy addition of other measurements, for example geotechnical or geophysical data. The entity-relationship diagram presented below shows the possibility of expanding the database with other groups of data (Fig.4).

![Entity-Relationship Diagram](image)

Figure 4. The entity-relationship diagram with the possibility of expanding the database

The database project shown in the figure above allows the database to be easily enriched with measurement results obtained for the same physical value and new groups of physical parameters measured for the area. Not only does it allow the storing of data related to monitoring changes in the given region of research, but it also provides easy access to this data for further analysis.

The table contains stratigraphic data, and with code selection allows the entering of new values of the position of the ceiling of geological layers. It is extremely important to take into consideration the specific nature of the area for which the database was created due, for example, to the likelihood of physical phenomena associated with mineral exploration.

Apart from objects in the database which store data about the analysed area, there are also objects responsible for data analysis and visualisation. The profile tables are an example of one such object and are responsible for collecting the data necessary to create geological profiles and the layerpoint table, which is used to create 3D sections.
3.3 System operation scheme

The general scheme of the work flow of the STRATOS system is shown in Fig. 5.

Access to this system is possible after logging in with a username and password. In order to create a new user account users simply complete the 'Add user' form with the appropriate information. There is also some basic account management functionality which allows administrators to view, edit and delete existing accounts. Each user can choose a custom stylesheet which defines the look of the page.

The first step which is necessary to perform the first login is to enter information on stratigraphic profiles. The data may be entered manually or imported from a file stored on the user's hard drive. The correct format for input data is a text file in which each profile is stored on a separate line with a tab character separating the parameters. The values in a row are respectively: ordinal number, type of profile, OG, hole number, X, Y, Z coordinates, and 18 values representing the distance between the ceilings of the individual layers of the land surface and the depth of the hole calculated from the surface. The data obtained in this way is permanently stored in the database and available for subsequent logins to the system.

The imported information is presented in a table in a window and can be edited directly. New records can be added, existing records can be checked or deleted and a comment can be assigned to each row. The user interface for this application is based on Telerik windows, making it possible to hide and move individual elements. An effect similar to a desktop application is achieved, and the need to reload the page content is eliminated.

Each column has grouping and sorting functions. In the illustration the data is sorted by year (Fig.6).

Profile data can be displayed in a graph which shows the distribution of the measurement points (Fig.6).

Information about each imported profile can be presented in a graphical RDLC report. The thickness of the layers is presented using the difference in the level lines, while signature marks and colours are chosen according to geological structure. The generated graphs can be exported to four types of document: PDF, TIF, MS Word and MS Excel.
3.4 3D Visualization

The main advantage of the system is the ability to create 3D visualisations of imported data (Fig. 7). A 3D model is displayed based on a grid of points generated from the data in the database. Calculating the coordinates of the model for all the points is a time-consuming process, and therefore does not take place each time the model is displayed. The data is interpolated and extrapolated into a rectangle covering all profiles stored in the program and then stored in a database table.

The algorithm calculates the point positions of the displayed model and takes a list of coordinates describing the analysed layer as a parameter. The input data obtained from mine differs from well to well, and there is a lack of information about different stratigraphic well depths. To deal with the problem of missing data, a method providing missing information on the basis of the coordinates of the closest layer above was used. This method can result in unnatural arrangement, especially in deeper layers where the amount of missing data is highest. All such anomalies can be corrected from the data editing window.
The resulting model is simplified in relation to the amount of input data due to the limitations of the technologies used. Too much information sent from the controller to the view affects page load times in the browser. On the other hand, the number of points drawn on a WebGL canvas significantly influences the performance of the computer when the application is open. For these reasons, it is not possible to display 3D models in a higher resolution.

From the tool window (Fig. 7) the model can be rotated around two axes: Horizontally on the Y-axis passing through the centre of the model and the perpendicular line of the model base, and vertically on the X axis. Rotation on the Z axis has not been implemented as the other two rotation axes are enough to sufficiently manipulate the model, giving the possibility to rotate it to almost any angle. The "Increase spacing between the layers" slider allows for a smooth change of the distance between successive layers.

The ability to generate cross sections was also implemented, allowing the model to be cut perpendicularly along the X or Y-axis.

The cross sections are displayed in the same window as the 3D visualisation, and switching between the 3D version and the cross section is carried out with the checkbox controls in the tools window. This allows cross-sections to be manipulated in the same way as the 3D model, with rotations, transfers, and the hiding of selected layers.

4 Conclusions and further work

We present a system for collecting, analysing and visualising 3D stratigraphic data. The developed web application gathers information in a database and uses it to generate RDLC reports with 2D visualisations and display 3D models using WebGL.

3D visualisation with the presented system requires relatively substantial hardware resources such as RAM and a powerful graphics card, but the goal has been achieved giving users a functional and relatively easy to use application. The results of the applied system and its smooth operation have been achieved through simplification of the model displayed because too much information affects page load time in browsers. On the other hand, the number of points drawn using the WebGL library significantly affects computer performance and efficiency while the application is open. For these reasons, it is not possible to display a 3D model in a higher resolution.

The system meets expectations. Future development will likely be focussed on highly improved performance, in particular improved 3D graphics and faster program start up time, which is dependent on the amount of data sent from the server.

Currently work is underway which aims to collect data related to the construction of the mine itself and place it in the STRATOS database system. The main objective for the future is the possibility to use the system not only to collect and visualise, but also to track the changes and expansion of a mine.

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References


