

MO2GEO - a Small Tool for Registration and Visualization of Geological Data

L. Schimpf and W. Gossel

Dept. Hydrogeology and Environmental Geology, Institute for Geosciences and Geography, Martin Luther University Halle, Germany

Abstract

Geological data have to be registered according to country-specific standards and visualized in 3D tools. Both topics are addressed by the tool MO2GEO, which is flexible enough to allow the insertion of common national geological standards (UK, Germany, US). Borehole graphics and cross-section development are available, and the database extended by these data allows for an improved interpolation compared to borehole data only. The visualization of the pseudo-3D volumes shows not only the connected surfaces of geological layers but also virtual cross sections and boreholes at any defined points or lines inside the area. The tool MO2GEO is OpenSource and can therefore be used in schools as well.

1. Introduction

Registration and visualization of geological data is a main objective of the Working Group of Hydrogeology and Environmental Geology, MLU Halle. Formerly, commercial tools were used for this task, but now the conditions for setting up a new OpenSource tool have improved rapidly. Geological data are registered heterogeneously based on diverse national or even company or institutional standards. These standards differ technically and in their registration structure of geological features, e.g., the BGS classification of igneous rocks [GS99] or the Symbolschlüssel Geologie [Pre10]. Commercial tools such as HGA (Schlumberger Water Services), GeoDin (Fugro Consult), GGU Software (GGU), Strater (GoldenSoftware), QuickLog (boring-log.com), PLog (Dataforensics), and gINT (Bentley) support only one or two standards or have their own registration systems. The geological 3D modeling tools such as GSI3d, move, Leapfrog, GoCAD, SURPAC, Rockworks, or Petrel use their own registration, which is not bound to standards and has to be classified strictly hierarchically before setting up a 3D model. Based on the borehole data and the cross section information the interpolation of surfaces is carried out either by geometrical or geostatistical methods. A more general tool for an interpolation based on isolines was developed in the frame of MO2GEO. A Nearest Neighbour method with simple smoothing option and an IDW application are planned and partially realized. Additionally, a data export is guaranteed that can be used by tools such as Surfer

(Golden Software) or any GIS system like Quantum GIS, ArcView with several extensions, SAGA GIS, or GRASS GIS, to name a few. The interpolation results are visualized in the form of surfaces or 3D bodies. Additionally, most tools allow a visualization of cross sections through the model (virtual cross-sections), which have to be separated from the cross sections for model construction and virtual boreholes at any point in the model area. MO2GEO also provides these features, so it supports further visual analyses. The visualization procedures are realised with OpenGL 3.2, which allows for effective platform-independent usage of the hardware components. Therefore, most of the tools run under Linux as well as under diverse Windows systems.

2. Methods

2.1. FieldModule

The FieldModule is built up from a very simple architecture that also reflects the aspired usage of the tool (Figure 1). The application itself is used for data input and output and visualization, whereas an object-relational PostgreSQL database serves as a data storage device. However, the key element of the FieldModule is the data processing, which can be separated into two essential scopes: database-relevant and visualization-relevant processes. PostgreSQL offers a pre-built library (libPQ) that allows an easy implementation of SQL in C++. It also enables the possibility to serve as database for PostGIS applications. The relations of the

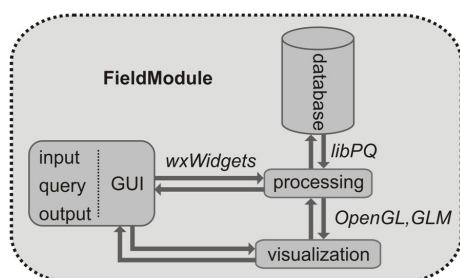


Figure 1: Architecture of the FieldModule with interfaces and corresponding libraries.

database can be separated into attribute and object tables. Attribute tables contain single information to describe user-defined objects. Both are used not only for recording geological data but also for storing the standards. At the moment, the database consists of 69 different tables. These tables form the MO2GEO FieldModule database scheme. In contrast to other databases, this scheme is not completely relational in its formation but is in some parts hierarchical. This was done to allow a project-oriented recording of the field localisations and a comprehensible implementation of hierarchical organized standards (e.g., stratigraphy). The FieldModule allows the use of different common standards, improvement according to local specifications, and even the setup of its own symbols within a database. By default, the standards listed in Table 1 are implemented.

Table 1: Default standards used in the FieldModule.

Standard	Application
Symbolschlüssel Geologie [Pre10]	Stratigraphy, different attributes
BoreholeML [Sta13]	Borehole description
Hierarchical classification of rocks [Isa11]	Consolidated and unconsolidated rocks
Guidelines For Soil Description [Foo06]	Soil description
International stratigraphic chart [Int10]	Stratigraphy
BGS vocabularies [Bri12]	Structural geology, different attributes
Digital Cartographic Standard for Geologic Map Symbolization [Uni06]	2D/3D drawing, signatures
GeoNames [Geo12]	Geography

The FieldModule application's principle task is to record, archive, and visualize geological issues by means of a graphical user interface. Using standards and ciphering should make this easier and clearer, and should also ease the data exchange. The software was written in C++ using the Code::Blocks IDE and MinGW for compiling. To realize the programming, four additional libraries had to be applied (see

Figure 1): wxWidgets (GUI), libPQ (database connection), OpenGL (visualization), and GLM (mathematics for visualization). As described earlier, the field data is recorded in a project-oriented hierarchy. This project can be of different kinds (e.g., geological mapping or a drilling project) and must be created first. Otherwise, no data can be recorded. The project can have an undefined number of different localities representing the "geological spot", which can be an outcrop, a borehole, or a fieldstone. To ensure a valid amount of data, the input follows a principle of minimal information content. This forces the user to assign at least these minimal informational attributes within a database object of the same type. Recording geological data is the core feature of the application. This includes lithological units and their properties and boundaries as well as palaeontological and structural data. One of the basic working methods in geological mapping is the separation of units depending on their lithological properties, which can be used for stratigraphical determination later [RAB*05]. This is also the basic concept for recording geological features with the FieldModule. A lithological unit can be described with up to eleven attributes. The corresponding standardized contents are summarized in nine database tables (Table 2).

Table 2: Database tables used for attribution (-H hierarchical structure).

Database table	Content - Standard
chronostrat -H	chronostratigraphy - [Int13]
color	colour - [Pre10]
compandelem -H	minerals, macerals, elements - [Pre10]
difaccum	accumulation, xenolith etc. - [Pre10]
geolprocesses	genesis - [Pre10]
magmprefix	magmatic attributes - [Pre10]
petrography -H	rocks - [Isa11], [Bri12], [GS99], [Rob99], [HK99], [SQD*02]
sedminorcomp	sedimentary minor components - [Pre10]
stratsymgeo -H	stratigraphy - [Pre10]

To avoid incorrect data and equivocalities the usage and also the usable content of these attributes is restricted by the chosen rock type. Another aspect in recording geological data is the description of fossil material which is very important for stratigraphical determination of lithological units. This data is directly linked to the unit where it was found. There are eight possible attributes for palaeontological data description of which three have standardized contents (e.g. taphonomy, common taxonomy and condition). The hierarchical taxonomy itself is not standardized by default but it is set up to use data offered by the Catalogue of Life [Cat13] or similar. Describing lithological units in a regional scale requires more or less static conditions. However there are a huge number of properties which can take various forms or even be absent on different localities (e.g. water content, weathering, boundaries, sedimentary structures, and discon-

tinuities). Because of this, a direct integration into the lithological unit is not possible. To register outcrop or geological data from boreholes a different approach was needed: A vertical profile line is used for record the data. Each point of interest on this line can be described separately. This allows describing multiple conditions within one lithological unit (Figure 2).

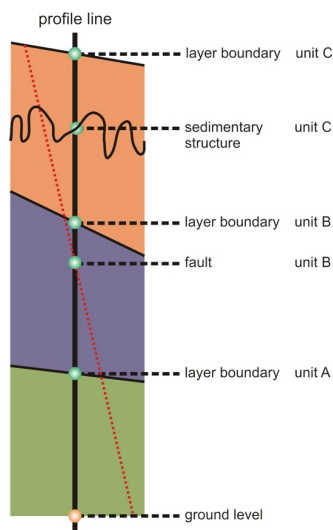


Figure 2: Registration of multiple features along a profile line in relation to lithological units (A - C).

The standards used here are taken from [Pre10] and [GBM11]. This also enables the possibility to create multiple profile lines for one outcrop. Creating the technical datasets of a borehole and well description (equipment, materials, methods, measurements, and samples) follows the same procedure as for the registration of those geological and structural features with standard attributes provided by [Com12] and [Pre10]. The registration of information along a vertical profile line facilitates also the visualization process. As already described before the visualization is realized using the OpenSource OpenGL API. To enable a RAM independent rendering of the contents, which allows separating the rendering process from data manipulation, OpenGL 3.2 was implemented. The data can be rendered in up to four viewports where each can show the same or varying content from different camera positions like in common CAD- or 3d-software. This gives the possibility to compare and control the geological data in a practical way. Figure 3 shows the standard visualization of outcrop and borehole data, which is organized tabular to visualize the gathered data in a compact, informative and user-friendly way. This table includes display areas for each individual attribute where either a graphical or a textural (standardized ciphering, abbreviation) representation of a data set is displayed. The visualization of the geological features is carried out as a classical outcrop pro-

file showing the lithological units as a graphical implementation. These graphical implementations use OpenGL textures which are created during the data input (geological and technical data) and consist of a colour and a signature based on [Uni06]. To allow the usage of drilling core sample images an UV-mapper was implemented to create the needed texture coordinates. The application is also capable to import and render ESRI and Surfer grid data (e.g. digital terrain models).

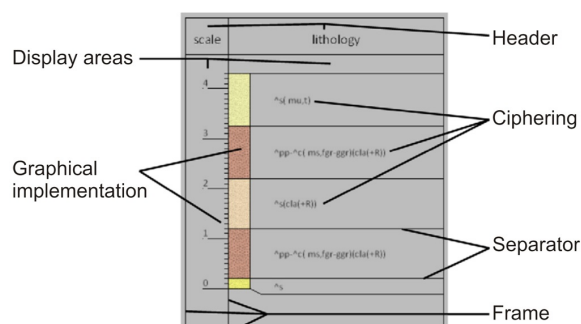


Figure 3: Tabular composition of the two-dimensional visualization of outcrop and borehole data.

One of the most common procedures in three-dimensional geological modeling is the construction of cross sections for the interpolation of strata surfaces. Looking forward to the development of a geological modeling tool this becomes a very important step. The visualization of the lithological units provides a base for the constructive creation of the cross sections by using the created sites as data points. The construction is done by choosing two lithological units which should be connected to one stratum or only one if the stratum lenses out and by drawing supporting points for a top and a bottom boundary. To triangulate the surface between these lines three triangulation methods were implemented: ear clipping [?], minimum weight triangulation [Meh01] and partition into monotone polygons [DBCVK08] (Figure 4).

Figure 5 shows a cross section which connects two lithological profiles of an outcrop. This cross section includes strata connecting two profiles as well as strata lensing out and sutural textures.

2.2. Interpolation methods

Via the construction of cross-sections, additional points are generated for the surfaces (or bottoms) of the geological layers. These points plus the points of the boreholes outside of the cross-sections are the data base for the interpolation of the surfaces/bottoms. The most appropriate interpolation techniques for this purpose are geometric ones like Nearest Neighbour, TIN or IDW. The Nearest Neighbour method with an additional smoothing option is planned and the IDW method is already partially realized but not integrated. An

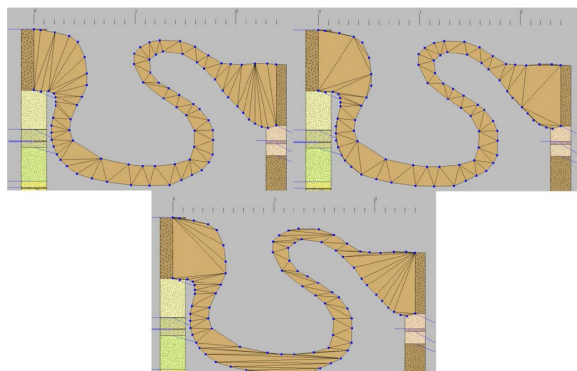


Figure 4: Resulting triangulation methods of a conceptual stratum. Top right: ear clipping. Top left: minimum weight triangulation. Bottom: partition into monotone polygons.

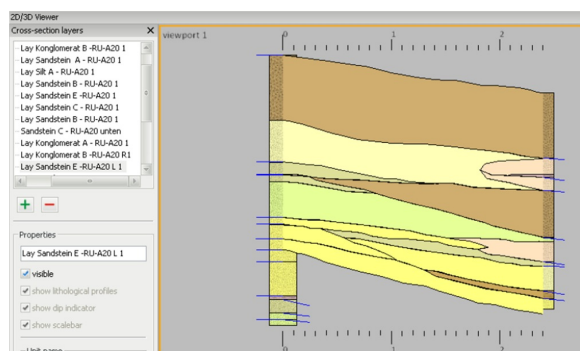


Figure 5: Cross section created with the MO2GEO Field-Module.

additional tool in the frame of MO2GEO is the newly developed L-IDW method [GCF12], which is not appropriate for the task described here.

2.3. Visualization tools

The MO2GEO Viewer module, shown in Figure 6, for the visualization of models was created by the working group to spread the developed 3d models to the public. Input data are plain ASCII grids, which are either produced by the interpolation tools of MO2GEO or by OpenSource GIS. The three-dimensional visualization and the generation of virtual cross-sections and boreholes in a three-dimensional model can be used for educational purposes as well as for professional questions and their solutions. The cross-section lines and borehole locations can also be imported via OpenSource GIS. Data exchange format is the Atlas BNA format which can be exported by the OpenSource GIS tools. For the virtual boreholes a manual data input is possible.

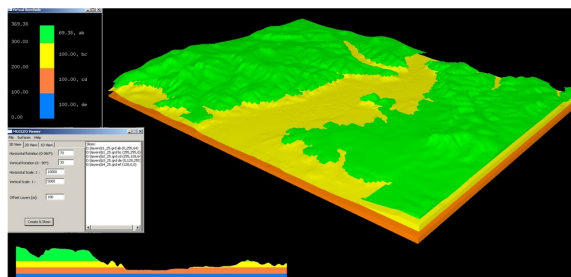


Figure 6: Overview of features in the MO2GEO Viewer module.

3. Results and discussion

The advantage of using OpenSource tools for geological data registration and visualization is of course the independency on commercial software and the ability to implement the interoperability of different existing software solutions. A lot of different user groups can benefit from this: The FieldModule is designed to be used by universities, companies and geological surveys to ensure the quality of data acquisition and a standardised way of registration and to give access to the first steps in geological modeling. The viewer tool can be used in universities, community facilities and even schools to explore 3d models. Another big advantage of OpenSource - the possibility to adapt code for different purposes - does not play a major role in this case, because the workflow of geological modeling and especially the visualization is quite straight forward and only data exchange is prone to improvement in code.

4. Conclusions and perspectives

Offering the ability of using standardized data is most important for the interoperability of geological databases and data exchange. On the one hand the further development of the tools will focus on the enhancement of the existing features and the interoperability and on the other hand the encapsulation of proper geologic modeling techniques. The focus will be on the implementation of more interpolation techniques, geometrical as well as geostatistical methods, to close the gap between the cross-section based constructive modeling approach and the 3d visualization. To accomplish this MO2GEO has to be extended and certain methods have to be developed in a new way. Parallelization of code is another sophisticated task that will enhance the performance and acceptance of these methods. The integration of the modules plays a major role for the applied user whereas the scientific is used to cross platform work and the application with big data sets. Both objectives will be scheduled in the development of MO2GEO because it is developed mainly for scientific work but the established tools can also be applied in public and project work.

References

- [Bri12] BRITISH GEOLOGICAL SURVEY: Vocabularies - further information, 2012. URL: http://www.geosciml.org/geosciml/2.0/documentation/cookbook/GeoSciML_Data_CookBook_V2.pdf.
- [Cat13] CATALOGUE OF LIFE (COL): 2013 annual checklist, 2013. URL: http://www.geosciml.org/geosciml/2.0/documentation/cookbook/GeoSciML_Data_CookBook_V2.pdf.
- [Com12] COMMISSION FOR THE MANAGEMENT AND APPLICATION OF GEOSCIENCE INFORMATION: Geosciml cookbook - how to map data to geosciml version 2, 2012. URL: http://www.geosciml.org/geosciml/2.0/documentation/cookbook/GeoSciML_Data_CookBook_V2.pdf.
- [DBCVK08] DE BERG M., CHEONG O., VAN KREVELD M.: *Computational geometry: algorithms and applications*. Springer, 2008. 3
- [Foo06] FOOD AND AGRICULTURE ORGANIZATION: Guidelines for soil description. *FAO, Rome, Italy* (2006).
- [GBM11] GILLESPIE M., BARNES R., MILODOWSKI A.: *British Geological Survey scheme for classifying discontinuities and fillings*. British Geological Survey, 2011. 3
- [GCF12] GOSSEL W., CHUDY T., FALKENHAGEN M.: Interpolation based on isolines: line-geometry-based inverse distance weighted interpolation (l-idw) with sample applications from the geosciences. 493–505. 4
- [Geo12] GEONAMES TEAM: Geonames geographical database, 2012. URL: <http://www.geonames.org/>.
- [GS99] GILLESPIE M., STYLES M.: BGS rock classification scheme, volume 1. classification of igneous rocks. 1
- [HK99] HALLSWORTH C., KNOX R.: BGS rock classification scheme. volume 3, classification of sediments and sedimentary rocks.
- [Int10] INTERNATIONAL COMMISSION ON STRATIGRAPHY: International stratigraphic chart, 2010. URL: <http://www.stratigraphy.org>.
- [Isa11] ISAAK S.: *Erfassung geologischer Sammlungsobjekte in aktuellen Datenbankmanagementsystemen (unter besonderer Berücksichtigung von Specify 6)*. Master's thesis, Diplomarbeit - Martin-Luther-University Halle-Wittenberg, Department Hydro- and Environmental Geology, 2011.
- [Meh01] MEHNEN J.: *Evolutionäre Flächenrekonstruktion*. Vulkan-Verlag, 2001. 3
- [One10] ONEGEOLOGY: Oneeurope onegeology - applying geoscience for society, 2010. URL: http://www.onegeology.org/docs/Oneeurope_Onegeology_eBook/flash.html.
- [Pre10] PREUSS H.: *Symbolschlüssel Geologie: Symbole für die Dokumentation und Verarbeitung geologischer Feld- und Aufschlußdaten*, 6 ed. Landesamt für Bergbau, Energie und Geologie Hannover, 2010. 1, 3
- [RAB*05] REMANE J., ADATTE T., BERGER J., BURKHALTER R., DALL'AGNOLO S., DECRUEZ D., FISCHER H.: Guidelines for stratigraphic nomenclature. *Eclogae geologicae Helveticae* 98, 3 (2005), 385–405. 2
- [Rob99] ROBERTSON S.: BGS rock classification scheme. volume 2, classification of metamorphic rocks.
- [SQD*02] STRUIK L., QUAT M., DAVENPORT P., OKULITCH A., ET AL.: A preliminary scheme for multihierarchical rock classification for use with thematic computer-based query systems. *Current Research 2002-D10* (2002), 9.
- [Sta12] STAATLICHE GEOLOGISCHE DIENSTE DEUTSCHLANDS: Infogeo.de - boreholeml, 2012. URL: <http://www.infogeo.de/home/boreholeML?lang=1>.
- [Uni06] UNITED STATES GEOLOGICAL SURVEY: Fgdc digital cartographic standard for geologic map symbolization: Reston, va., 2006. URL: <http://pubs.usgs.gov/tm/2006/11A02/>. 3