# Advancement of Geoservices

## *Services for Geoscientific Applications based on a 3D-Geodatabase Kernel*

**Martin Breunig, Wolfgang Bär and Andreas Thomsen**
**Research Centre for Geoinformatics and Remote Sensing**
**University of Vechta**
P.O. Box 1553, D-49364 Vechta
**e-mail:{mbreunig, wbaer, athomsen}@fzg.uni-vechta.de**

## OBJECTIVES

Coming geoservices will provide ubiquitous access to geodata. Therefore the efficient exchange of geodata will be a central and critical task (Giguère, 2001; Breunig & Bär, 2003). The requirements on versatility, interoperability, portability and performance of mobile and distributed geoservices are considerable, as are the requirements on 3D and 4D geodatabases in a distributed and mobile environment. Such geodatabases must efficiently manage a huge number of large and complex application-specific objects like 2D, 3D and spatio-temporal models. The necessity to achieve a clear, reliable and not overly complex implementation has to be weighted against the requirements on flexibility and performance of the management of complex geometric and topological objects on the database server, as well as against the requirements on interoperability and speed of data transmission in an environment of low bandwidth.

In this extended abstract we discuss object-oriented 3D geodatabase services to be used in a mobile environment. In the first section, we discuss the requirements of geological applications for the management of 3D geodata, with reference to the common application scenario presented by the Karlsruhe partner project. We briefly outline the main design and implementation choices, and then present a complex 3D-to-2D service. Tests with large 3D geometry objects show the different performances of page-server and object-server based architectures. Finally we give a conclusion and an outlook on our future research work.

## REQUIREMENTS OF GEOSCIENTIFIC APPLICATIONS

### Complex models of the subsurface

Whereas classical GIS-applications generally represent the surface of the earth by 2D/2.5D geometry models, geological applications concern the subsurface, and therefore use genuine 2.5D/3D geometry models. There is, however, another feature that distinguishes geological modelling apart from classical GIS: the subsurface in its entirety is not accessible to observation. Therefore the position, form and structure of geological bodies must be inferred from spatially limited observations, e.g. by statistical estimation, or by the interpretation of seismic data. A lot of geological background knowledge is necessary to achieve a useful model of the subsurface, which will always be subject to a considerable uncertainty.

The maps and sections used by geologists are always only so many projections of and cuts through a background model that has undergone a number of interpretation and estimation steps. The introduction of informatics permits to communicate such knowledge not only by 2D maps and sections derived implicitly from geometry models, but to make the process of geometrical modelling of the subsurface explicit and communicable. Present-day 3D-modelling tools allow several geologists to co-operate during the establishment of a subsurface model, making the process of modelling reproducible.

### 3D geometry and topology combined with thematic attributes

Database services for subsurface geology applications must provide access to entire 3D-models, as well as to 2D representations (projections and sections) derived therefrom. Whereas in the case of mostly undisturbed sedimentary bodies, triangulated 2.5D surfaces representing strata boundaries may be sufficient, the general case comprising also important faults and folds, or non-stratiform bodies (e.g. salt-domes) requires true 3D-models. A geological subsurface model consists of a *structural model* of the geometry and topology, and a *property model* of the thematic attributes. Different approaches to 3D modelling can be distinguished: regular and hierarchical grids, 2D and 3D simplicial complexes, free-form surfaces and 3D volume bodies in boundary representation, as well as hybrid approaches. In our project, we restrict ourselves to 2D and 3D simplicial complexes and boundary representation of complex 3D-volume objects. Thematic attributes attached to geometry objects provide a flexible way of managing a simple property model.

**Database services, modelling tools and on-site clients**

The system of distributed geoservices developed in this joint project consists of on-site clients for data acquisition, viewing and augmented reality, which are developed by our project partners in Munich, Heidelberg and Karlsruhe. These clients communicate over network with the geodatabase services presented here. Besides an efficient 3D-geometry database providing shared access, storage and retrieval, and a comprehensive set of services providing problem-specific operations and transformations, a distributed environment for geological applications requires a powerful interactive 3D-modeling system. We use GOCAD® (Mallet, 1992) as modelling tool and concentrate our research on the 3D-database and basic geometric/topological operations.

**Transactions and versions**

In a distributed and mobile environment, a 3D-geometry database server for geological applications should enable the geologists in the field, as well as in the laboratory, to refer to a shared common model of the subsurface during the process of data caption, processing, interpretation and assessment. The cycle of steps involved in updating a geological model can be long, however, and the result may never be free of subjective appreciation. Therefore, rather than supporting direct editing by transaction management, it is advisable to use strategies of version management to control the evolution of the shared model.

**Restrictions on the client side**

A comprehensive subsurface model may consist of hundreds of geological bodies, each represented by complex objects, e.g. triangulated surfaces, composed of up to more than a hundred thousand elements (e.g. triangles). Considering a portable client instrument, e.g. a robust PDA combined with a GPS client, both the transmission and the graphical representation of such a complex model are not yet realistic, because of insufficient available bandwidth and performance of the graphical display. On the other hand, the geoscientist in the field often needs only a selected part of the information, specified by e.g. a 3D-region, a stratigraphic interval, a set of thematic attributes and some other geometric and thematic criteria. Even such a reduced information may be too large for use in the field, motivating the use of techniques of data reduction and progressive transmission (Shumilov et al., 2002). Graphical representation of a 3D-model can be reduced to a sequence of 2D-sections and projections that are displayed using the limited graphical capabilities of a mobile client. By sliding through successive sections, even a 2D display can provide insight into the form and structure of a complex 3D body.

## DESIGN CHOICES

**Object-Oriented DBMS**

Since a number of years, the object-oriented approach to geometry modelling has been well established. In the domain of database management, however, object-oriented DBMS have not succeeded in supplanting the so-called object-relational approach, i.e. the extension of relational databases by some object-oriented features. We decided to use a genuine OODBMS as basis for the 3D geometry database, because of the more straightforward mapping of geometry models onto persistent storage. Performance considerations led to the choice of a commercial Object-Oriented DBMS with page-server architecture.

**Interoperability**

Interoperability can be supported in different ways. Whereas CORBA (OMG) technology can be used to achieve a flexible connection between clients and servers in a heterogeneous environment (Shumilov, 2003, Shumilov et al., 2002), we chose the Java programming language for portability, XML for flexibility of data exchange, whereas the invocation of specific services of the 3D database over the network is supported by java-based JINI (Waldo & Arnold, 2000). XML today is in widespread use for flexible data exchange in a heterogeneous environment. Because of its extensibility, XML can practically be used to express any object-oriented data structure, though at the cost of considerable redundancy, which however can be reduced by the use of general-purpose compression techniques. Moreover, the XSL transformation language XSLT provides tools for transformation between different XML representations.

## 3Dto2D SERVICE FOR GEOLOGICAL MODELS

In the application scenario described by our Karlsruhe project partners, geological profile sections serve as the basis for the construction of a 3D-geometry model. Such 2D sections, however, also provide the classical means for the investigation and visualisation of complex geometries. Therefore as a concrete geological application we discuss the 3Dto2D geoservice. It provides all the necessary functionality of information reduction from complex 3D models to 2D models in order to make the model usable and displayable on constrained client devices (PDAs). Such a service on a mobile device will allow the field geologist to compare the actual observed situation with information provided by the subsurface model, and to take decisions on sampling accordingly.

The 3Dto2D service provides the derivation of 2D profiles from a 3D model. It is composed of the following elementary services:

- *RetrieveService* – supports queries for the complex geological objects.
- *PlaneCut* – cuts a planar profile through the 3D model for a given plane.
- *PlaneProjection* – projects objects onto the plane profile.
- *AffineTransform* – transforms the resulting 3D object into a 2D xy plane.

The construction of piecewise planar profile sections by repetition of these operations with different parameter values is straightforward. The computed result from the 3D model of this service will be a 2D map in the xy plane representing an arbitrary plane profile through the model with additional information projected onto the profile. Figure 1 shows the principle steps of the 3Dto2D service.

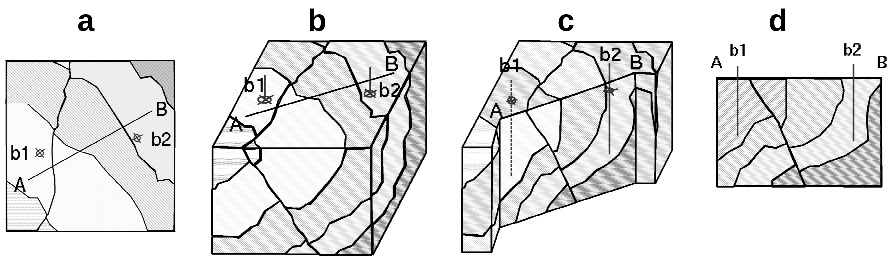


**Figure 1** Example of a 3Dto2D service: Planar profile section between endpoints A and B, with projected borehole profiles b1 and b2. (a) – location in map plane, (b) – block view of 3D model, (c) – view of profile section with part of model removed, (d) – resulting 2D profile section with the projected boreholes.

Each of the elementary services implies a large amount of geometry operations, and in consequence requires a considerable amount of time. Therefore, in order to reduce the length of transactions, the elementary services of which this 3Dto2D service consists of, are operating each in transactional mode. Single failures of an elementary service can be compensated by restarting the elementary service, and do not require starting the whole process from the beginning.

The results of this and all other geoservices made accessible by our DB are delivered as a custom XML representation. As such, the results can easily be transformed with XSLT to other XML representations as GML in 2D, X3D in 3D or any other textual format like VRML, GOCAD ASCII etc.

## PERFORMANCE TEST ON GEOMETRIC QUERIES

The performance tests for the object-oriented data stores were performed respectively with a page- and an object-server based system architecture of an OODBMS. We examined different spatial queries for the retrieval of the internal geometric elements of a complex geological object. Such object internal queries are used in almost all geological algorithms based on the optimisation through internal spatial indexing of the complex object elements.

For the performance tests we used simulated geometry objects from the CS-department at Bonn University (Breunig et al., 2001). For each architecture, a test database was built consisting of two triangulated surfaces comprising 100,000 and 200,000 triangles. Then different spatial queries on the internal geometric elements of the complex objects were executed. Table 1 and 2 show the times needed for the insertion of the surfaces into the test databases as well as the retrieval times for different spatial queries. The spatial join query between the two intersecting surfaces resulted in a set of 1,979 intersecting triangles. The window queries, performed with two different query sizes, resulted in 1,144 (5%) and 61,255 elements (25%).

| Page-server based data store | | Number of triangles in the surface | |
|---|---|---|---|
| | Unit | 100000 | 200000 |
| Insertion | Minutes | 0.6 | 1.2 |
| Spatial Join | Seconds | 44.3 | |
| Window Query 5% of space | Seconds | | 1.9 |
| Window Query 25% of space | Seconds | | 33.5 |
| Nearest Neighbour | Seconds | | 1.2 |

**Table 1** Results for the page-server based system architecture of an OODBMS

| Object-server based data store | | Number of triangles in the surface | |
|---|---|---|---|
| | Unit | 100000 | 200000 |
| Insertion | Minutes | | 42.2 |
| Spatial Join | Seconds | 233.3 | |
| Window Query 5% of space | Seconds | | 8.1 |
| Window Query 25% of space | Seconds | | 234.6 |
| Nearest Neighbour | Seconds | | 2.5 |

**Table 2** Results for the object-server based system architecture of an OODBMS

Clearly the page-server architecture outperforms the object-server architecture for this application, due to the large number of internal elements of the complex geological objects. A triangulated surface with 200,000 triangles comprises, including internal R*-tree objects and internal topological relations, approximately 1,100,000 individual objects. Under such a load the object-based server turns into a bottleneck through its objects-based network transport and its object-level locking. The page-server architecture benefits from the fact that it groups about 150 to 200 small objects onto one page which also is the level of locking and of transport over network.

## CONCLUSION AND OUTLOOK

We have presented requirements of geoscientific applications for 3D geometry data management services. We briefly discussed a geological application scenario and a geoservice for mobile devices. A performance test on a simulated data set showed the advantage of the page-server over object-based architecture for very large complex objects. In future work, we will extend our research on geological services based on object-oriented data stores towards further types of services, especially to the management of spatio-temporal data for mobile geological services.

## REFERENCES


Breunig,M., Bär,W.: *Usability of Geodata for Mobile Route Planning Systems.* Proc. 6th Int. AGILE Conference on Geographic Information Science, Lyon, 451-462, 2003.

Breunig,M., Cremers,A.B., Müller,W., Siebeck,J.: *New Methods for Topological Clustering and Spatial Access in Object-Oriented 3D databases.* Proc. 9th ACM GIS, Atlanta(GA), 10p., 2001.

Giguère,E., *Mobile Data Management: Challenges of Wireless and Offline Data Access.* Proc. 17th. Intern. Conf. Data Engineering, Heidelberg, IEEE Computer Society, Los Alamitos(CA), 227-228, 2001.

Mallet,J.-L., *GOCAD: A Computer Aided Design Program for Geological Applications.* A.K. Turner (ed.), Three-Dimensional Modeling with Geoscientific Information Systems, NATO ASI 354, Kluwer Academic Publishers, Dordrecht, 123-142, 1992.

Shumilov,S.: *Integrating existing object-oriented databases with distributed object management platforms,* PhD dissertation, Bonn, 2003, 245 p.

Shumilov,S., Thomsen,A., Cremers,A.B., Koos,B.: *Management and Visualisation of large, complex and time-dependent 3D Objects in Distributed GIS.* Proc. 10th ACM GIS, McLean(VA), 2002.

Waldo,J., Arnold, K.: *The Jini Specifications*, 2nd edition, Pearson Education, 2000, 688p.