A NEW APPROACH FOR 3D-CARTOGRAPHY: OBJECT ORIENTED TECHNOLOGY TO COMBINE GIS AND CAD

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Abstract

Currently, one of the main challenges of geographic information systems (GIS), is the development of their capability of using and considering three-dimensional entities. This is the reason behind our work, which offers the geo-scientist and engineer a working environment that combines the tasks of construction, visualization and storage of such data. For the development of applications, we base ourselves on an object library. By way of demonstration of the possibilities of our system, we are developing components that help in solving structural-geology problems.

1. Introduction

Understanding physical phenomena in the Earth Sciences, involves the modelling of natural entities in three dimensions. In the modelling process, the geo-scientist must be able to build, see, inform, store and retrieve objects, in order to use them for computations and simulations. Such activities generally are called **3D-cartography**. Ideally, the geo-scientist expects the following services from this tool:

- storage and retrieval of raw data;
- visualization and interactive query of the available information;
- data interpretation, i.e. constructing the geometry of, and assigning values to geologic attributes;
- association of physical parameters, such as density or permeability, to its objects;
- importing from and exporting to external (existing) applications, such as meshing or simulation.

Off-the-shelf tools, such as database systems, 2D-spatial-analysis tools, image-processing systems and CAD systems, can fulfil part of the requirements, but generally do not address the whole problem. Moreover, many such tools view the third dimension as just another attribute of the objects, i.e. the geometry in not 3D *per se*, or the 3D is built on top of 2D primitives. Finally, each of these applications was designed for a specific requirement, rather than for a process as a whole; this means that little thought was given to the proper interaction between such software systems, and that their integration usually requires the development of filters working through unwieldy ASCII files.

In short, the effort required to assemble such different components is huge and generally does not even lead to satisfactory solutions in terms of technology, maintenance and cost.

This paper is organized in five sections: the analysis of 3D cartography; the requirements for an operational 3D cartography, the realization of such a system; and the conclusions where we discuss our approach.

2. 3D-Cartography

Operational 3D mapping requires the consideration of several critical points. *First*, the 3D representation of natural objects usually requires large amounts of raw data (e.g. a digital elevation model), can involve complex forms (e.g. a salt dome), and may require complex expert knowledge to build an accurate model. The construction process should use geological as well as topological or geometric constraints. Data volume and representation scale commonly have been limiting factors in current attempts.

Secondly, as mentioned before, the exchange with existing applications is a major issue. Much investment (development, training, installation) generally has been made in such tools, most of which do well what they were designed for.

Thirdly, for large companies, such as BRGM, there will never be one tool that fulfils all requirements. In the competetitive market, we have to find solutions that allow us to build the widest range of tools for the greatest variety of geo-sciences, but at the lowest cost. As the introduction of 3D processing is recent, the demand is imprecise and subject to change. The environment should thus be smart enough to cope with substantial evolution.

Fourthly, recent times have seen profound changes in the way geo-scientists operate: they increasingly work in multi-disciplinary teams; they share data and usually compile these in complex syntheses. In the longer term, we should be able to provide the geo-scientist with a workstation that will federate the use of various tools in an environment that is homogeneous in look and feel, working principles, access methods, etc.

Functions	Tools
Map creation	Micro Station (Intergraph)
2D spatial analysis	SynerGIS (BRGM) Arc/Info (ESRI)
Data management	Oracle (Oracle)
Map editing	SynCompo (BRGM)
Image processing	Imagine (ERDAS)
Geo-statistics	GDM (BRGM)

Table 1 - Examples of existing tools

3. Approach and strategy

As seen in Section 2, the problem to be solved is complex, and inaddition we did not have the resources to build a new solution from scratch. We thus chose to tackle the problem by reusing an existing application that would handle the heaviest part, i.e. 3D modelling, and constructing our library on top of it [2]. Rather than developing a unique application, we selected an environment that would bring us a library of components to re-use and enrich. From this basic library, we will build domain-specific systems.

Hovewer, to be successful with this strategy, our basic system had to be carefully chosen. Table 2 summarizes the key points of consideration.

4. CASCADE

After a careful examination of the commercially available software, we selected the CAS.CADE package that was developed by Matra/Datavision [3]. Table 2 mentions the choices made by Matra for the critical points that we had to address.

CAS.CADE correctly addresses the technical points, and even goes further in its design capabilities to build new software applications. It particularly offers a wide range of possibilities to run a system over a heterogeneous network of distributed machines (Fig. 1).

Criterion	Examples	CAS.CADE
Implementation must be compatible with object-oriented development	Use a class, inherit from it and build new ones	C++ implementation, design language CDL (~ Eiffel)
Object library	Model geometry and topology	BR topology, CSG modelling API, NURBS geometry
Function library	Visualization, user interface, meshing, etc.	PHIGS visualization, Motif user interface, Delaunay triangulation
Data management	Data scheme, entity, relationship, aggregate and inheritance, query language, data sharing	Objectivity
Long-term usage and portability	Standards (implementation language, libraries, database management system)	Graphics PHIGS and PEX, interface MOTIF, front end LISP, import/export STEP; version Sun/Solaris, DEC/OSF ...
Ease of use	User interface, documentation, training and support	Analysis environment with CDL, development environment C++, user interface in LISP
External application dialogue	SynerGIS, Arc/Info, Oracle	Standard Unix (C calls, dynamic library and sockets), etc.

Table 2 - Description of CASCADE

5. Developed solution, the demonstrator

In order to meet our requirement for the widest range of domain-specific applications, we used an object-oriented technology for our development. This meant the design of a generic architecture based upon a common object library [4]. This library will be completed by the development of specific applications. Figure 2 outlines the concepts used in our solution.

The common library addresses the following points:

- presentation of the geological objects on the screen;
- construction and transformation of geometries;
- management of values associated to attributes for each geological object.

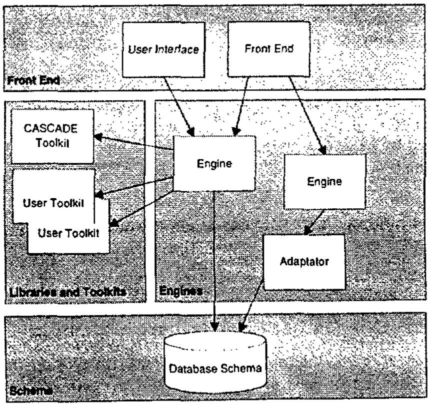

Figure 1 - The CAS.CADE architecture

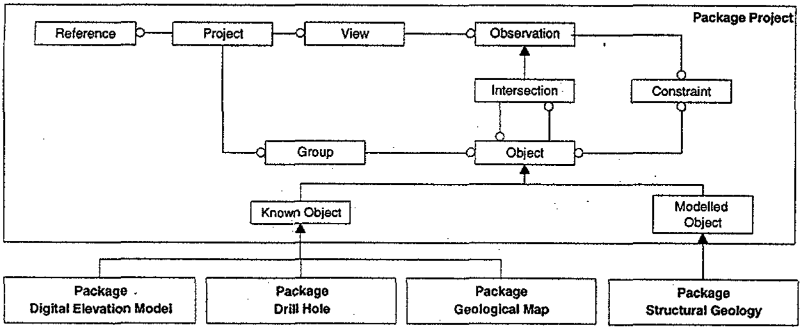

Figure 2 - Outline of the common library

We focused our development work on the domain of structural geology, and designed a specific set of classes (Fig. 3) as well as a toolbox for the structural geologist.

This demonstrator [7] helps the geo-scientist with the automatic 3D construction of a surface from a set of elevation data (DEM). After this, he can plot on this surface all geological data from maps, and site the locations of boreholes on the same surface. As a second step, he can add vertical cross-sections that describe the geometry of geological objects, such as layers, faults, folds, etc.

Currently, we are developing classes for the following domains:

- generalized maps [5],
- automatic 3D reconstruction of surfaces and volumes from basic data, using Voronoi 3D diagrams [6],
- automatic 2D reconstruction of cross-sections from incomplete information

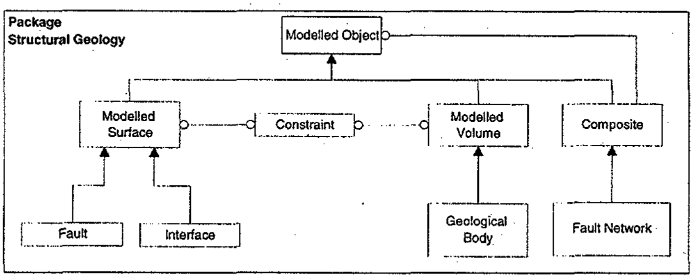

Figure 3 : Classes for structural geology

6. Conclusions

Up to now, CAS.CADE has completely fulfilled our needs. It is a great help in building a library with geological components. The way the applications are constructed enables the creation of new ones through the assembly of parts of existing applications. The database scheme guarantees their integrity for different applications and provide a free and efficient comminication system. As soon as the user-geologist will design a new class, any previously used classes can incorporate the newly developed component without losing the earlier established information.

We are convinced that this is the only rational approach for adding 3D-cartography techniques to the panoply of R&D teams, but staying within an acceptable cost range. The investment for the first application may seem heavy (acquisition of software, training and support), but the end result will be of top quality. The major inconvenient at present seems to be the dependence on CAS.CADE and our research includes the clear identification of links with foreign classes.

7. Bibliography

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