

3D Modeling and Visualization

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Abstract

This paper presents our experience in applying 3D modeling for processing and visualizing geoscience's information since more than 10 years. Subsurface characterization is important in a number of geological activities including petroleum industry, waste deposit, natural resources (mineral and water), geotechnical engineering and environmental applications. However, it faces a lack of information because the subsurface is usually investigated from irregular sampling points (bore hole, outcrop sampling, seismic sections) making the topology of the underlying real object unknown. This uncertainty as to real shape implies that classical CAD approaches might be irrelevant, as shown by several pioneer works. The situation can be further complicated by the presence of discontinuities such faults, fractures or folded layers. This is why the natural object approach has been developed specifically to handle complex natural 3D objects. It involves specific data structures, information system, logical and topological constraints that will be shortly presented. Implementation of such notion has been performed in gOcad using objects oriented programming. The knowledge is included in the modeling using a set of constraints. Several cases studies will be presented for illustrating the method and concepts.

Introduction

Extensive work has been done in the area of 3D Visualization and modeling using CAD approach [11]. These methods can be selected into two categories: namely, *CAD objects* and *natural objects*.

CAD technology, usually based on the Bézier type of curves or surface (Splines, Nurs), requires the *topology* of objects at the conception and elaboration stages (i.e. the geometrical and spatial relationship between objects or part of objects). It mainly concerns manufactured or industrial goods. Triangles or tetrahedral elements are used to fit the surface or the volume of the final object using splines, Bi-splines, or Bezier interpolation methods. Several industrial CAD systems are based on such a concept and are widely used in the industry among the most popular ones AutoCAD and Strim 100. If this technology is perfectly adapted to industrial design since the early 1970's, it is irrelevant for modeling the subsurface geological objects [2]. The reason is simple: when designing an industrial good the topology of the object is perfectly known and the purpose is to manufacture a good locking product adapted to a list of functions. When building a 3D subsurface model, the aim is not to produce artistic shape but to respect the available measurements given some constraints: the *topology* is the result of this interpolation not the a priori, a more complicated task.

Natural objects are usually investigated from irregular sampling points (bore hole, sections, points), the *topology* of the underlying real object is not known.

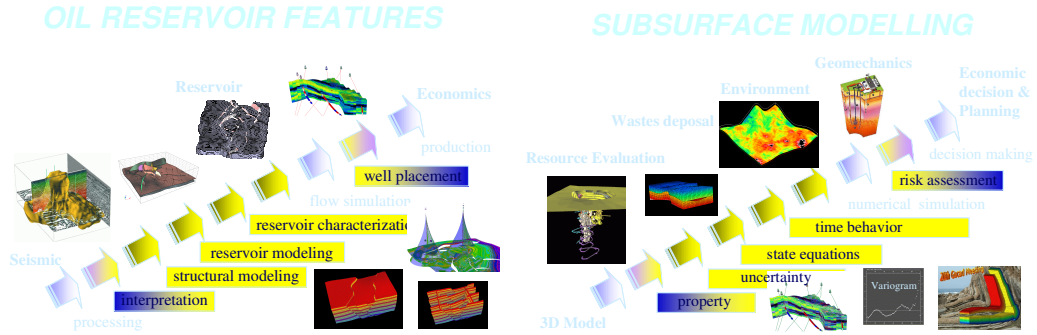


Figure 1. Sequential steps involved in 3D earth modeling: deep reservoirs (left); subsurface geology (right).

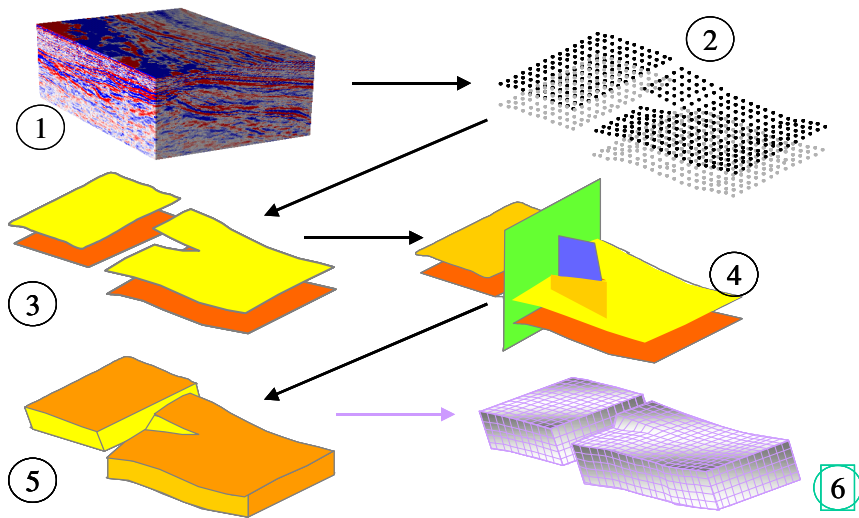


Figure 2. Deciphering the topology of a complex geological structure : (2) picking geological horizons from 3D seismic cube (1); building the interfaces as triangulated surfaces (TSurf) (3); identification of faults (4); extracting the volume of the layer (5); meshing the layer (6) in order to define properties.

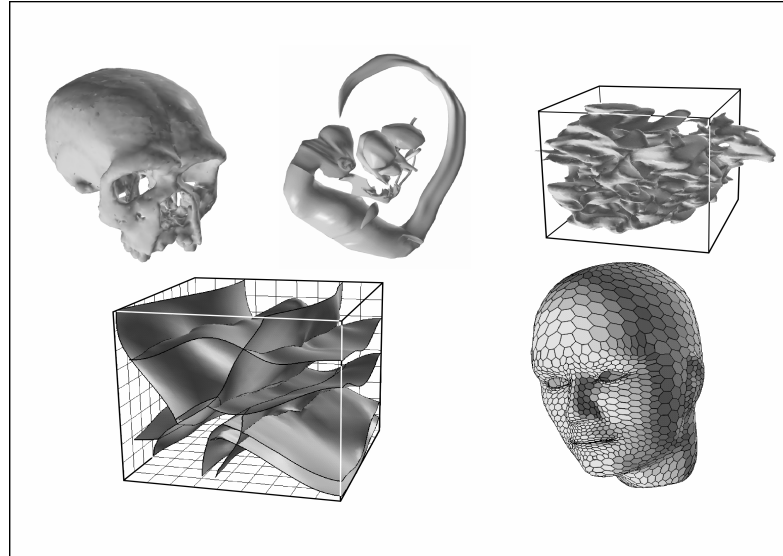


Figure 3. Some Geomodeling applications.

The complexities arising also from the presence of discontinuities such faults, fractures or folded layers, are specific to geoscience for several reasons:

- The subsurface data are *heterogeneous*. They must account for (i) *exact location* (from well data or sampling points.), (ii) *dipping* when available from well data, (iii) *imprecise data* (location of horizon from the seismic), (iv) *soft data* (qualitative information, constraints such this horizon is under this formation); (v) *structural data*.
- The subsurface data are collected at *different scales*. A centimeter scale characterizes well data while seismic is blind less than 5 meters [6].
- The subsurface data are more or less precise. *Uncertainty* is a characteristic of underground investigations. Generally speaking data along well trajectory are more reliable than seismic one [1, 8].
- The subsurface data are generally *irregularly sampled*. Most of the time, they are clustered because of well location or outcrop sampling. This clustered data makes unstable most of the usual interpolation techniques (kriging, B-splines) [7];
- The *topology* of objects is unknown [6].

The complexity is taken into account in the *topology*, a key feature indeed, which distinguishes the classical CAD approach.

Methods in 3D Modeling

New technologies have therefore found to be necessary to model natural objects in 3D. In gOcad, the chosen technology is based on a *discrete approach* for modeling objects. This approach is specifically designed to handle the complexity mentioned above [2]. Two steps are required for building a model:

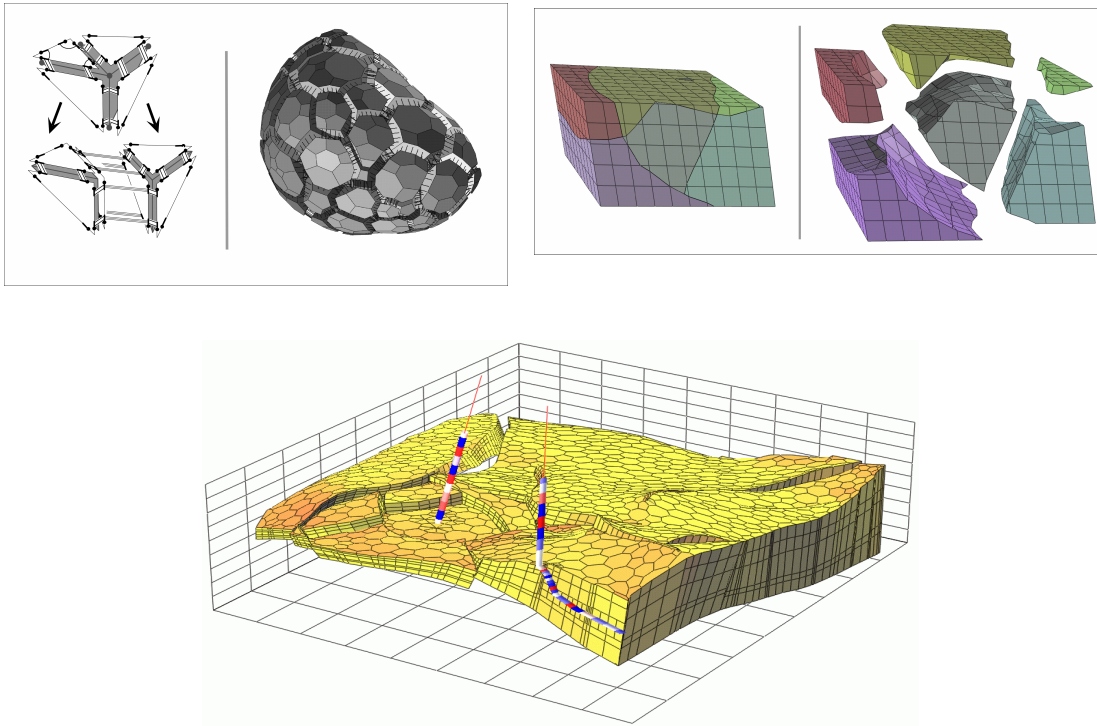


Figure 4. The G-Map approach is a new concept for modeling the topology. Examples of cellular partitioning using G-Maps.

- (i) construction of the *geometrical model* from the available observations. It is done using elementary elements such as points or atoms, lines (PLINE) and surfaces represented by a set of triangles (TSURF). The volumes are defined using meshed tetrahedral, cellular, voxet or stratigraphic grids (SGRID). Specific interpolation algorithms have been developed to estimate location of uninformed location (Discrete Smooth Interpolation [4, 5, 6]);
- (ii) construction of the *property model*: Once the geometrical model is built, the physical properties are estimated at all locations in the 3D space. Properties are attached to location (*atoms*). Refinements based on G-map structures including topological relationships between basic elements have been proposed recently [3, 5]. It generalizes the notion of property, which can be attached to all kinds of objects (surfaces, tetrahedra, lines...). This method also increases the rapidity of algorithms involved in geometrical operations such as cut, union, intersection, updating deformation [6]

Advanced mathematical techniques have been investigated such as interpolation methods for continuous and qualitative data accounting for uncertainty (Discrete Smooth Interpolation [4], stochastic simulation [9], geostatistics [10]). Parameterization of irregular meshed grids, streamline and fibbers are also used for modeling and interpolating properties in complex faulted structures. Implementation of such notion has been performed in C++ in gOcad.

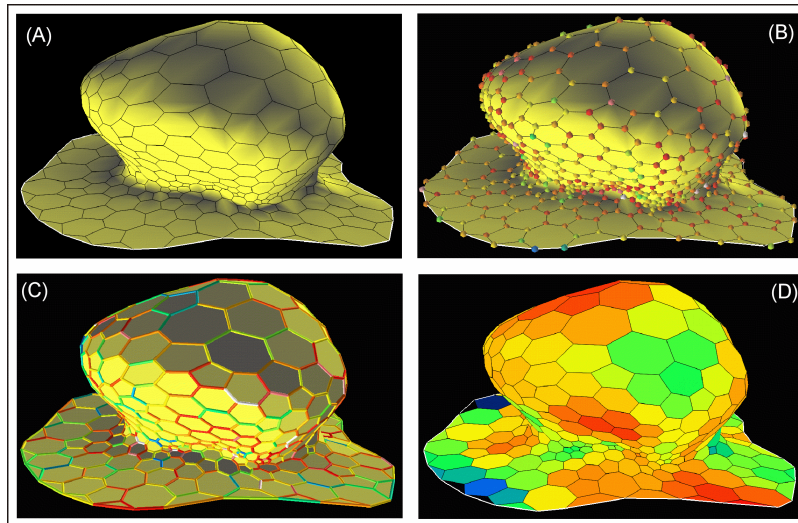


Figure 5. Interpolating properties on complex geological structures (after [6]).

Visualization and validation of the model - The visualization is done interactively using the gOcad software [4, 5, 6], a powerful tool designed for the interactive 3D modeling of the subsurface involving geophysical applications such as 3D ray tracing, 3D tomography and migration, reservoir simulation of complex geological structures (reverse faults, salt domes, etc.). It comprises a *Geometrical Data Base* specially designed to efficiently carry out operations such as (i) *intersection, union of two or more surfaces*, (ii) intersection of a surface by a line (ray tracing), surfaces or volumes; (iii) storage of physical properties attached on a layer (velocity, density, porosity, permeability,) or a volume (VOXET).

The visualization of the information contained in the database is done interactively under the QT. The code is written in C++ in an object-oriented style. An independent 3D graphic library has been developed in order to *simplify the portability* of the software including the following interface X graphic interface, GL, Phigs+, Starbase, Xgl, Pexlib, and QT. The code runs currently on Linux, Unix and Windows operating systems. Additional information about this system can be found at the following URL <http://www.ensg.u-nancy.fr/GOCAD/> or in "gOcad project" [3], managed by the Association Scientifique pour la Géologie et ses Applications (ASGA), Pr. J.L. Mallet, Chairman of the Computer Sciences Department of the Nancy School of Geology, Nancy, France.

More than a software – Today, the gOcad system is more than a 3D modeling software. It provides also the users a general environment tools for developing specific user applications using the objects, data-structures and user interface available in gOcad. DDL libraries offer useful connection with the object database. Corba protocols can be used to retrieve and shared common objects, providing the users the possibility to develop their own specific applications as *plug-in*. A programming language, called *script*, allows the users to write macro for visualizing or computing.

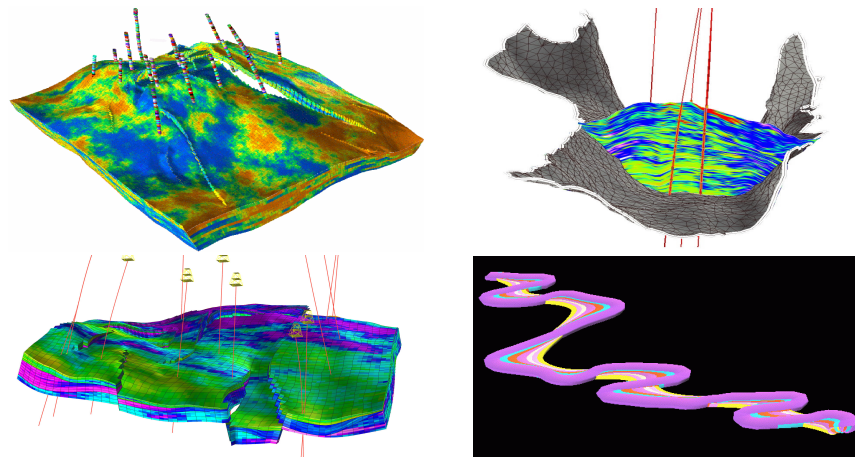


Figure 6. Interpolating properties on some complex geological structures: from left to right, top to bottom, (a) faulted porous reservoir; (b) porosity mapped on a vertical cross-section; (c) reproducing facies from well measurements [10]; (d) simulating meandering channel.

Guidelines for advanced processing techniques, such as property modeling [6], unfolding, simulations of uncertainty, geostatistics [7], etc are proposed to the user as *workflow*. A *workflow* is a list of parameterized pre-programmed tasks that can perform advanced computation depending on the parameters and choices entered by the user.

The gOcad Story a Research Model - The gOcad Research Program was initiated in 1989 by the Computer Science group of the National School of Geology in Nancy, France. This project is currently undertaken in collaboration with the Institut National Polytechnique de Lorraine (INPL) and the Centre de Recherches Pétrographiques et Géochimiques (CNRS), France.

The goal of this project was to develop a new computer-aided approach for the modeling of geological objects. This approach was specifically adapted to Geophysical, Geological and Reservoir Engineering applications.

An international consortium was created since it was clear that the national institutional research funding structures are inadequate for supporting a project such as gOcad and this is why, in 1989 Jean-Laurent Mallet took the initiative to create the gOcad consortium. The primary purpose of this consortium was to financially support and control the research activities performed in the frame of the gOcad project. In addition, direct interaction with sponsors allows the gOcad research group to concentrate its efforts on problems directly linked to the industry needs.

The consortium is widely open both to the industry and universities around the world who are interested in the new approach to geomodeling proposed by gOcad and want to use and/or contribute to the development of this new technology.

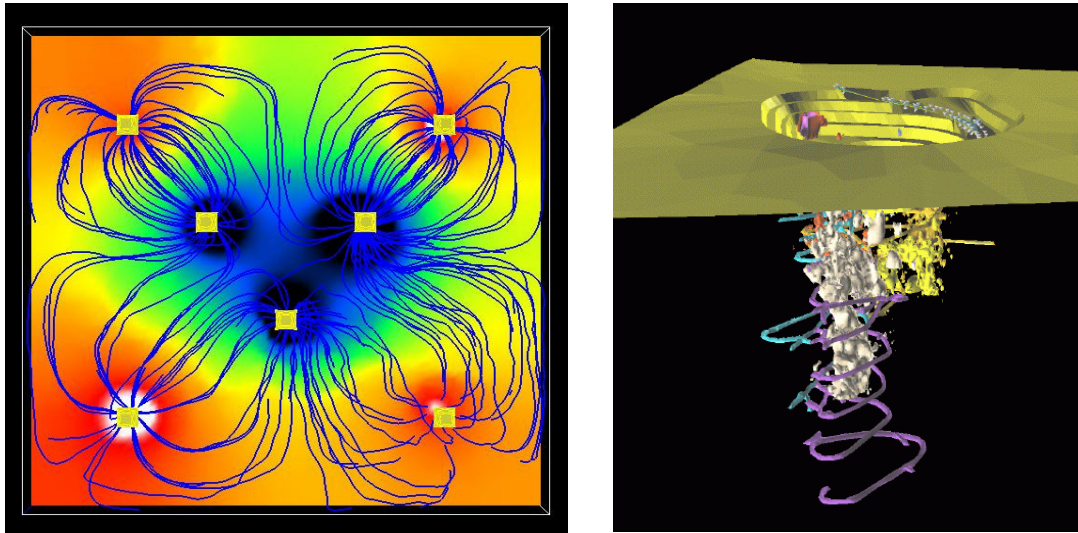


Figure 7. Left - Simulating fluid in a porous reservoir. Complex diffusive equations (saturation, tracer tests are) solved along the particle trajectories, called streamlines. Right - 3D modeling of a uranium open-pit mine, galleries in pink, ore bodies in yellow.

Today, the gOcad consortium consists of 23 companies and 72 universities, currently administered by the "Association Scientifique pour la Géologie et ses Applications" (ASGA).

The goal of the gOcad Research Consortium is to develop new algorithms to model the sub-surface geometry and properties. All the tools developed by the research consortium have been typically provided to the member of the consortium inside the gOcad application. In 1998, to open the access to the technology to more people, the Consortium decided to let the T-Surf company (<http://www.t-surf.com/>) commercialize the industrialized official version of the gOcad software. The gOcad Research Consortium now focuses on exploring and delivering new prototypes of modeling tools as gOcad application plug-ins. T-Surf mission is to integrate these new tools inside the official version of the gOcad software called "gOcad kernel".

Each year, the sponsors are invited to attend gOcad meetings : The gOcad spring technical meeting (one full week), which is held in Nancy (France), generally in June. The gOcad fall users meeting (one day) which is held in the USA in conjunction with major conventions such as the SEG or the SPE.

The gOcad spring technical meeting in Nancy is the opportunity for the gOcad research group to present a series of papers and demos corresponding to the annual research results. These papers are assembled in a technical report available to all the sponsors. Moreover, the 'non-intrusive' source code (defined below) of the software prototypes developed by the gOcad research group is also available to all the sponsors in the form of separate software modules called "plug-ins".

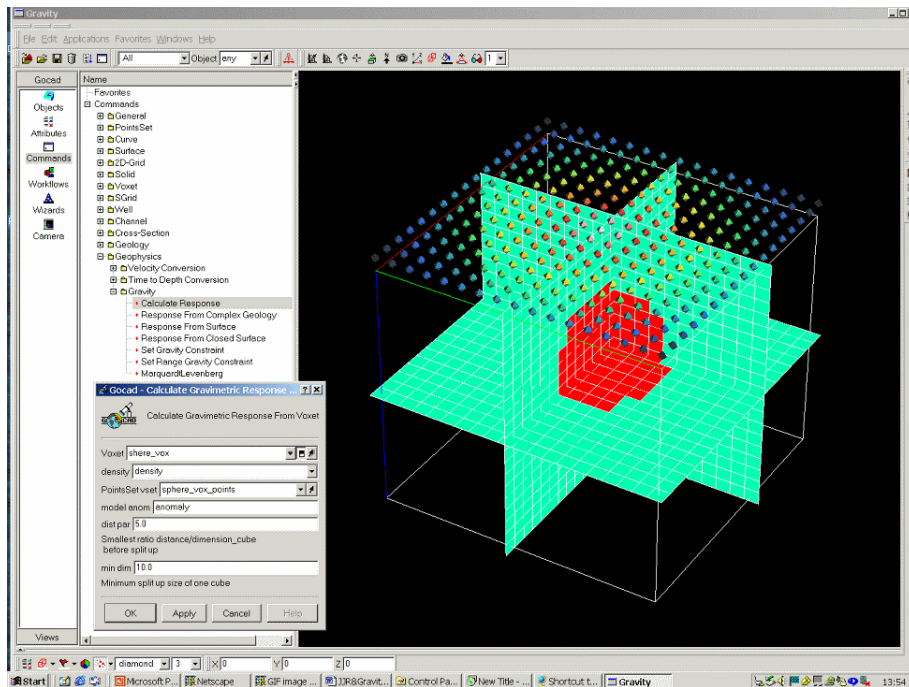


Figure 8. An example of a gOcad user interface: This plug-in computes the gravimetric anomaly at the surface induced by a 3D buried geological body.

Results

Some of results obtained by gOcad on different situations are illustrated on figures 1 to 7. It concerns both the construction of a geometric and property model for exploitation of mineral resources. The core of gOcad is built around a set of C++ object structures. A handler based on menus manages the interface between the user and gOcad. It includes the notion of multi windowing (called 3D camera) in which the user can visualize virtual 3D object. Language script can be used to perform arithmetic transformation on properties. A communication process library using TCL assumes interface between external applications. It provides the user a powerful tool for modeling complex object. Future development are actually understudy especially link with network technology.

A 3D browser including elementary methods for visualizing, transforming objects including intersection, evolution through times, deformation,... is under development using Java. It may allow the user to visualize a gOcad object created on a specific platform on other computers. Specific compress techniques are required in order to decrease volume of data transfer.

Conclusions

Modeling complex natural objects appears clearly an important challenge. Significant results have been already obtained [5, 6], nevertheless, some problems remain difficult to solve, concerning the data (management of huge amount of data, different scales, different dates). Several directions are offered with the development of the information highway including

parallelization of the computing through the web, data spreading on several computers accessible through the WEB, WEB database, multi visualization sites using Java technology. It promises exciting research area and issues for the future of the visualization of information and data.

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