# Three-dimensional Visualization of Geological Units Represented by Spatial Subdivisions

Extended Abstract

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## Introduction

In the search and exploitation of oil and gas reservoirs, one of the tasks of subsurface petroleum geology is the mapping of unseen structures that may exist underneath the earth's surface. Geologists use 2D tools, contour maps and cross sections, to interpret geological data. However, spatial relationships presented in three dimensions are easier to interpret than a series of 2D representations.

The aim of this work is to evaluate the use of a spatial subdivision methodology in the representation and visualization of 3D geological models (called block diagrams). This methodology models heterogeneous objects (with dif-

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ferent parts made of different materials), by decomposing the space into homogeneous parts, and then describing the way they are connected.

# Methodology

This problem is treated by creating and maintaining a spatial subdivision, defined by a set of surface patches. The main goal is to provide a layer of abstraction capable of hiding the geometric and topological problems which occur when one creates and manipulates spatial subdivisions. The study of arbitrary spatial subdivisions extends and unifies the techniques used in non-manifold solid modeling and allows the modeling of heterogeneous objects, such as block diagrams.

A pertinent problem is: given a set of surface patches (or just patches), how can one obtain the spatial subdivision determined by these patches? In this work, it was implemented a software package intended to create and maintain spatial subdivisions with generic region shapes, allowing the insertion of new patches in real time.

This incremental procedure is a natural approach for modeling geological block diagrams. The model can be generated inserting families of joint planes (rock fractures) and rock layer boundaries (called horizons), which divide regions with distinct lithological properties.

# Representation of spatial subdivisions

Situations where more than two faces are incident to the same edge, or many volumes are connected by a single vertex, are common in a spatial subdivision. For this reason, its representation must be capable of storing in some way this type of condition. Several works have presented methods to represent spatial subdivisions. Rossignac and O'Connor (1990) have treated the general problem of representing n-dimensional objects, possibly with internal structures. Some data structures used in nonmanifold solid modeling (Weiler, 1986; Dobkins and Laszlo, 1987; Laszlo, 1987; Lienhardt, 1988) represent, in a general way, the adjacency relationships of three-dimensional objects not necessarily homogeneous in dimension. Here, we use the data structure proposed by Weiler (1988).

This data structure is known as *radial-edge*, because it stores explicitly the list of faces radially ordered about an edge. The radial-edge data structure is intended to be used in nonmanifold modeling and Weiler has proved its completeness, which means that any adjacency relationship can be extracted from this representation.

Weiler has also introduced a set of operators that provide a high level method to access the radial-edge structure. These operators are divided in two groups. The first group has operators that act on faces of a spatial subdivision and are analogous to the (two-manifold) operators presented in (Mantyla, 1 1988). The second group has operators that are capable of creating wireframes and of adding faces, which are "stitched" to specified edges or wireframes. These are referred to as *nonmanifold operators*.

## Spatial subdivision creation

A procedure which inserts surface patches in a spatial subdivision must guarantee its topological and geometrical consistency after the insertion. Topological consistency is naturally maintained by the appropriate use of the operators on the data structure mentioned above. To achieve this, an incoming patch must be subdivided in a set of patches, called *simple patches*, completely contained in regions of the subdivision.

To subdivide a surface patch it is necessary to find the faces of the subdivision crossed by the patch and the curve segments determined in each intersection. These segments are used to refine the surface patch and each crossed face. This refinement can be done by inserting each curve segment in the appropriate faces. Once both the incoming surface patch and the faces crossed by it have been subdivided, we have a set of simple patches that fit in the subdivision. Thus, the problem is now reduced to inserting new simple patches. To reduce the complexity of the algorithms, the refinement procedure exploits, as much as possible, the adjacency information provided by the data structure.

## Visualization strategy

The proposed data representation is also very helpful for model visualization. It is simple to "turn off" (to make invisible) a block. This effect is accomplished simply by not displaying the faces on the boundaries of the invisible regions. In addition, a useful visualization tool is to provide real time cuttings of the block diagram.

The central point of this visualization strategy is to suggest the user a solidity property for the block diagram model. Although the model is represented in the data structure as a set of solid regions, its exhibition on the screen is always performed by displaying the surfaces on the boundaries of the regions. The strategy accomplishes its objective because it automatically creates, in real time, fictitious faces at the cutting planes. The colors of the corresponding cut regions are assigned to these faces. The solidity sensation results from the display of the fictitious cutting faces in addition to the non-clipped surfaces. The same procedure described previously to insert a new surface patch in a spatial subdivision is used for the creation of the fictitious cutting faces.

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