An Approach on the Modeling and Visualization of the Geological Scene

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Abstract

The present work is a reflection on the modeling of a 3D geological scene with the aid of the graph technique of a software tool called PCheGeol(Cheaito, 2013)based on object-oriented programming, starting from a simple object, a set of object layers are placed one upon the other. These objects undergo a set of deformation processes (similar folds and faults), by the interpretation of the chronological history describing the set of folds and faults which are the origin of the current geometric form(Amrouch, 2010).The most common modeling is the technic of static modelingprogrammation(Leon, 1991),starting from a set of points or data, and by the interpolation and extrapolation, in order to describe the real geometric shape regardless of the essential features that realize the actual form of the geological scene. Since the work based on the technic of dynamic modelingprogrammation (Cheaito, 1993 and Perrin, 1993)has always problems with the quantity of data, our approach was based on the mixed BSPtree (Binary Space Partition) data structure to realize such a model. This allows obtaining a flexible model of the visualization of 3D objects and the manipulation of these objects to obtain the cut section and block-diagrams as well as to realize the level lines. It also describes the interior of the object by conserving an optimized quantity of data.

1. Introduction

In geology, as in many other areas, a model is the essential tool that allows to an observer the apprehension of realistic physics. However, a question arises about the modeling sequencethat allows givingthe data of observation of the image that we want to obtain from the geological scene(Cheaito,1993).This sequence can be described by the following schema (figure 1). A geological object can be always defined as the interior volume of a unique surface(Basei et al., 2010) whose external envelope is reduced to the calculation of the surface generated by the static model, starting from a discrete number of points belonging to this surface and by interpolation to see the final form of the surface.The main tools used to solve this problem are the interpolations of the type of surface of Bezier or B-Spline (Leon, 1991).Hence, our approach consists of modeling the geological processes which are at the origin of the actual from of the geological scene, and we are interested in two types of processes: similar folds and similar faults.These two types of processes are discovered by the geologists by starting from simple objects (a set of object layers are placed one upon the other) by conserving their chronological order.The geologists are generally interested in the shape of objects but not in their reduction (Douillet et al., 2013). For this reason, we define the different geological bodies by using only solid polyhedral objects limited by plane facets. Each polyhedral object is considered as "regular", which yields that the surfaces limiting the corresponding volumes are connected, oriented, non-auto-intersected, and of finite dimensions(Mortenson, 1985).The envelopes that limit each facet must themselves verify the property of non-auto-intersection(Mantyla, 1988 and Schlager, 2010).

2. Geometrical Constraints on the Operators

The definition of the operators simulating the geometrical consequences of the geological processes is suspected to be at the origin of the scene is of the center of the generative approach that we have chosen.

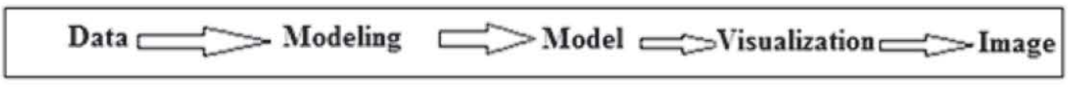

Figure 1: Modeling sequence

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These operators are acting on a whole or part of the objects of a scene permitting to transform it into a posterior scene (direct process) or anterior scene (inverse process).Thus, it is possible to realize such a scene containing a folded ground by applying it to a scene of departure formed of a stack of plane layers, where one or more operators are simulating the fold. Conversely, it is possible to reconstruct the scene of departure by applying a reverse order of the folded stage of the inverted previous operators, assuming that they are invertible.The choice of such a structure must be made according to the demands made by the model that we plan to achieve. These are of different natures:

-Requirements related to the geometrical characteristics of objects. The created and manipulated objects should be in all cases valid, according to the criteria of Requicha(Requicha, 1977).
-Requirements related to the mathematical operators used to simulate the geological evolution.The chosen structure must allow an easy implementation of the chosen operators, and more precisely the transformations of similar type operators (simulating folds and faults).
-Requirements related to the storage requirements of the model and the minimization of the computational time.

3. Deformation of the Geological Scene

The similar folds that are flexible deformations are the most widespread on the lands, after having undergone in-depth deformations can be represented geometrically by a model in which the planes are oriented in a special direction called "fold", and slip one on another alongside a determined direction called "sliding direction" (Douillet et al., 2013).

-In the case of a fault, respectively for all the points that belong to the one or the other half of the spaces are limited by the fault plane.
-In the similar case of a fold, for all the points that belong to the same sliding of the plane.The movements of the different material points,which are parallel in the two cases to a fixed direction having the same value. Thus, the defined transformations are called "similar type" (Perrin et al., 1988), and they are characterized as follows (figure 2):
-By a plane direction (plane of a fault or axial plane).
-By a right direction in this plane (sliding direction).
-By a function profile F(X).

The Transformation of Similar Type (TST) defined by (Perrin et al., 1988, Perrin and Peroche, 1989 and Perrin et al., 1987) is a point M(x, y, z) that is transformed to a point M'(x', y', z') such that $x'=x$, $y'=y$, and $z'=z+f(x)$.

The simulation of the complex geological transformations can be obtained by layering several different TST, the corresponding transformation express itself under the form seen in figure 3(Cheaito, 1993). Here:

n: denotes the number of applied TST.
M_i's: denotes the matrices of the transformations of each of these TST in a local indicator which is bounded.
$\Phi_{i,i+1}$: denotes the matrix that allows the passage of the indicator of the transformation of i into i+1.

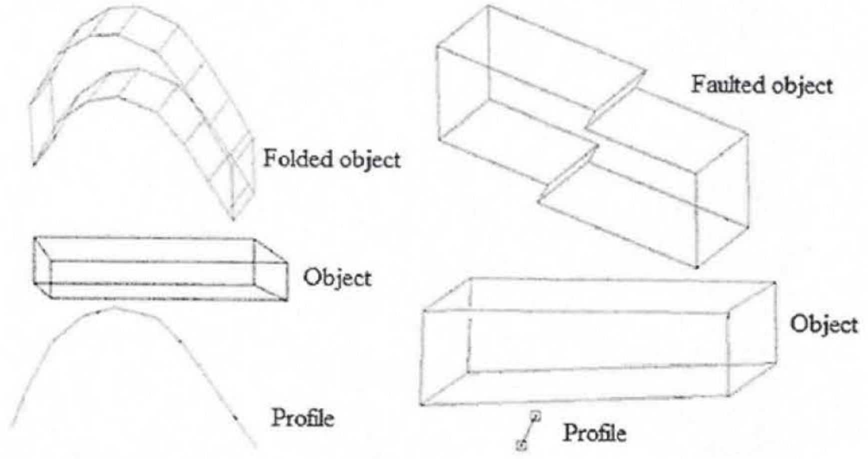

Figure 2: Elaboration of similar folds and faults

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = P^{-1} * \left(\prod_{i=1}^{n-1} M_i * \Phi_{i,i-1}\right) * M_n * P * \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

Figure 3: Geological transformation

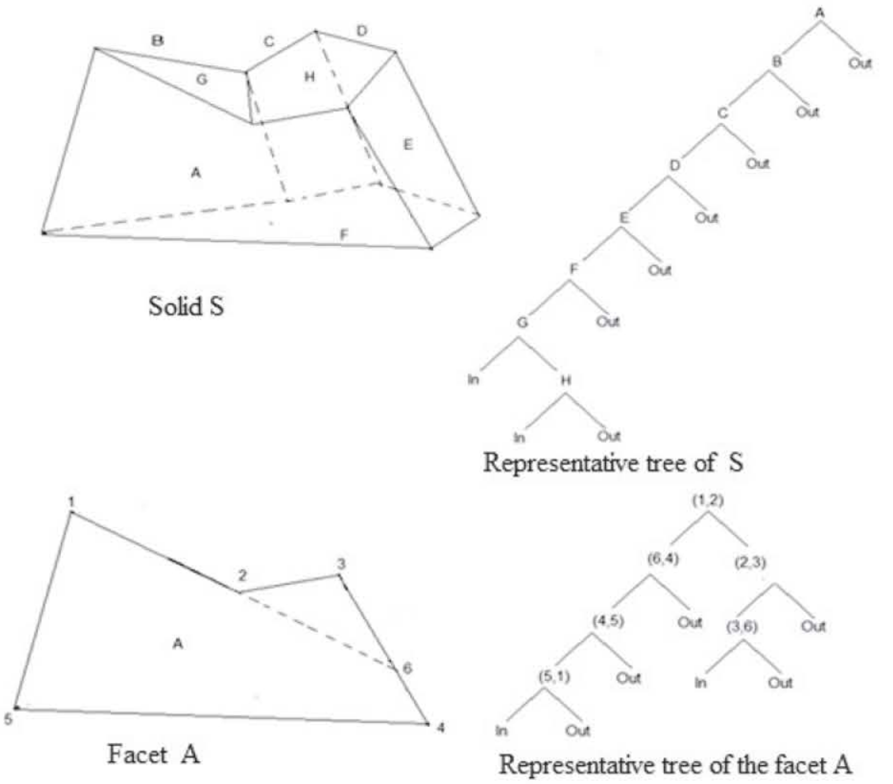

Figure 4: Representation of the mixed BSP tree

The interest of these types of transformation is due to the fact that itpermitsbuilding analogous land, having undergone excessive and complicated deformations. In fact, the obtained result from the application of the initial stratification leads to two similar types of transformations or give more complex figures that simulate sometimes in a relatively realistic way (Perrin et al., 1993).

4. The Polyhedral Objects

A choice must be made,when cutting to pieces (regular grid or not) and overall when referring to the nature of the elementary surfaces used to approximate the actual surface: plane facets, quadrics(Levin 1979),free surfaces adjusted on points belonging to the boundary of the model, surfaces ofcoons, of Bezier (Sohel et al., 2010 and Bezier, 1986)and rational B-Splines(Fahmy and Fahmy, 2012, Lizhuang et al., 1993).In the case that we are interested in, we saw that the geologists are more attracted to the restitution of a global accurate form that easily manipulated by a more or less smooth and pleasant exterior appearance of the surface of the represented objects. In the measure, where it is possible to approximate a very thin surface that we hope by a sufficient number of plane facets, we don't examine here other than the case of polyhedral solid. We then consider that the objects to be represented are limited by polygonal plane facets.

5. Geometrical and Topological Consistency

We could imagine representing the external surface of an object by simply providing a list of all plane facets belonging to it. Such a representation is called a "surface".The principle of the binary partitions of the space:In its principle, the structure of a binary partition of the space (Lysenko et al., 2008) is based on the recursive use of plane separators dividing equally a given space (Fuchs et al.,1980, Naylor, 1990 and Naylor and Thibault, 1986).

6. Definition of the Mixed BSP Tree, Representation of Objects

The representation of the boundary (Wang, 2010) of the described objects is not regarded as that in the available classic works done on the BSP tree(Wang and Manocha, 2013).We propose to include this by mentioning, the nodes of the BSP tree, the right sections or the plane separators that effectively correspond to the boundary of the sections as seen in figure 4(Lysenko et al., 2008).

7. The Algorithm of Constructing the Mixed BSP tree

To construct the mixed BSP tree nodes, we begin by insertinga facet "F" in the tree as seen in figure 5.

8. Visualization of the Solid S

By only one passage of the given mixed BSP tree that represents the solid S,we can eliminate the hidden facets as seen in figure 6.By passing the representative tree of S, we get that the facet is seen, otherwise it is hidden.In the above figure 6, A and F are the only seen facets.To obtain the final image of the scene, we can use the z-buffer method (Kolivand et al., 2011 and Ize et al., 2008).

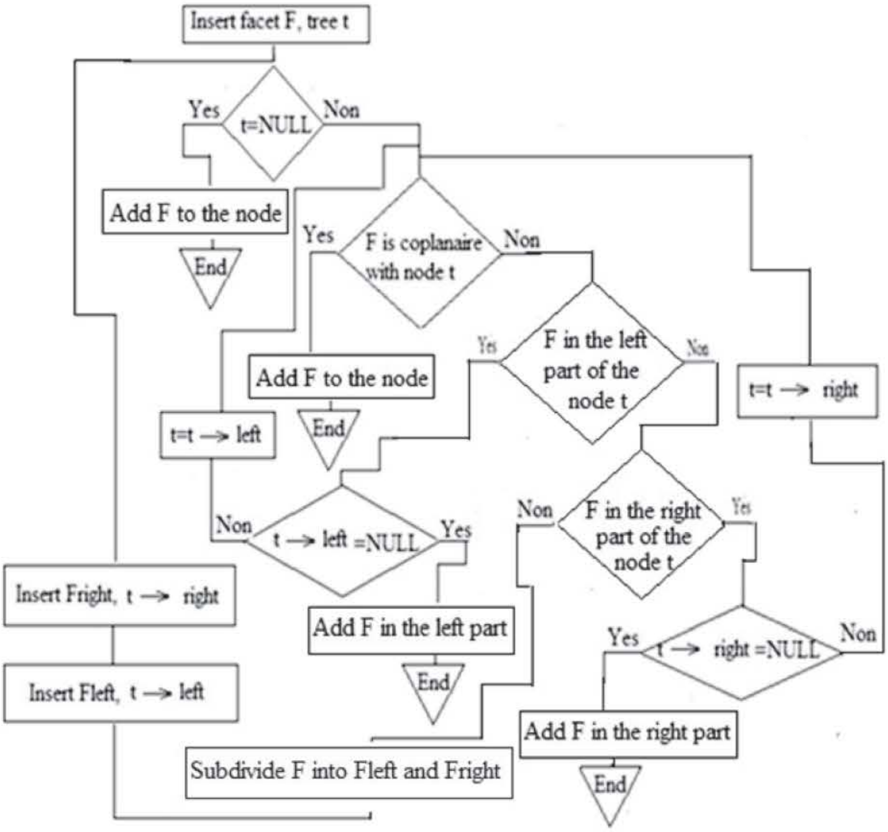

Figure 5: Insert a facet into the tree

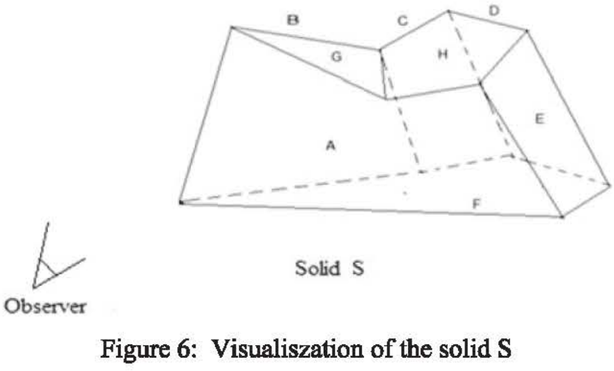

Figure 6: Visualiszation of the solid S

9. Some Technical Results

The following figures are the technical results taken from the software PCheGeol.PCheGeol is a computertoolbased on object-oriented programming that was developed and implemented within the IT department of the Lebanese University(Cheaito, 2013). It allows the modeling of 3D geological objects based on the dynamic modeling process, starting from a simple object we can obtain complex geological objects.On the other hand, the first figure describes the result of a real scene of an object that undergoes one TST deformation. The second figure shows the visualization of the object in 3D with and without colors. While the third figure, gives a description of the different possible phases applied to an initial object (Figure 7, 8 and 9).

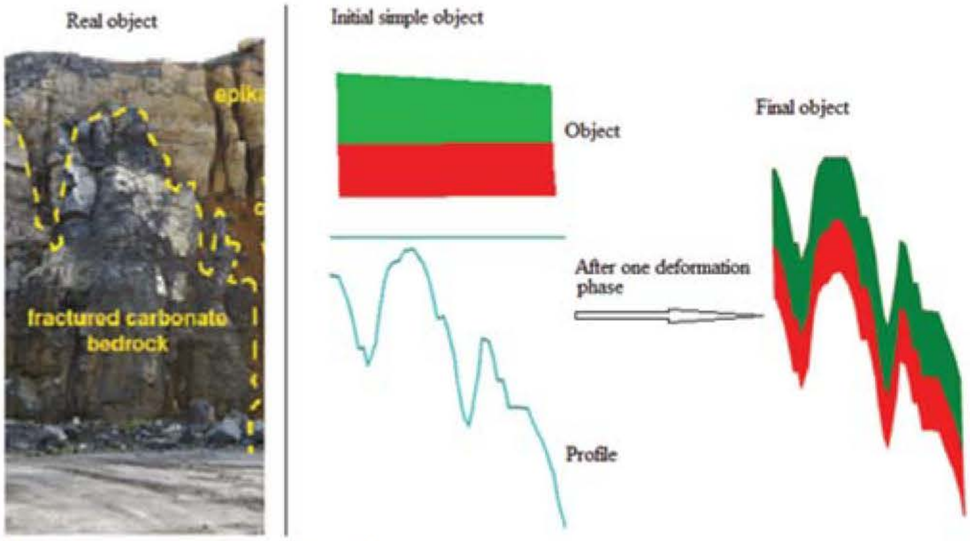

Photo showing vertical conduits within the epikarst exposed in a quarry south of Martinsburg, West Verginia, (Yager, Plummer, Kauffman and Doctor 2013)

Figure 7: Scene after one TST (realized by PCheGeol)

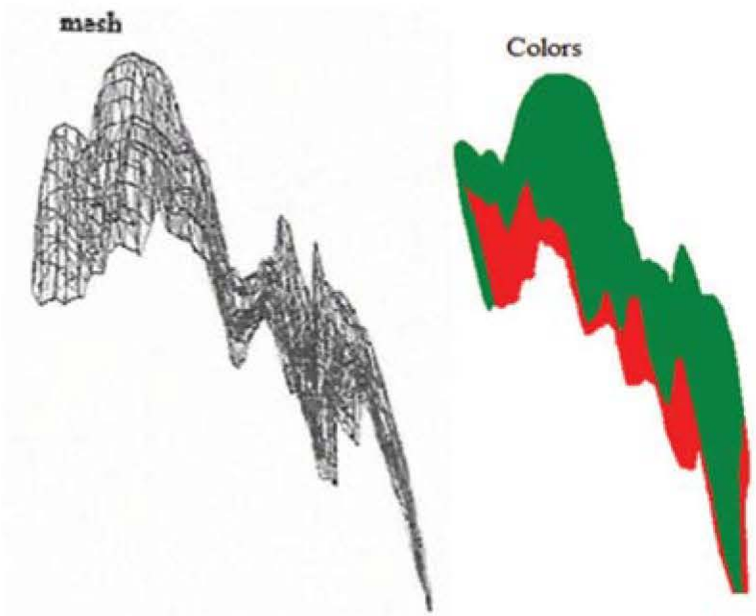

Figure 8: 3D visualization of the object given in figure7 (realized by PCheGeol)

10. Conclusion

This present work consists of an approach of some problems posed on the 3D representation of a "geological scene" using PCheGeol software.The obtained results in this work show the flexibility and the effectiveness of the proposed method. We have started from an object of departure relatively simple and we have arrived at complex objects describing the sequence of geological processes that interfere with these objects.The binary partitions of the space, of type BSP, have an undeniable interest in the measure where they appear much easier to implement, and equally in the measure where the problems of the topological validation of objects do not practically arise. In addition, the structure supports firmly the affine transformations.This reflection was conducted by taking into account a particular problem:the representation of a geological body of a complex form that is eventually deformed or deeply intrusive.This approach of dynamic modeling makes the representation of a geological model of complex form which is eventually intrusive so simple to be realized. By describing the geological processes interfering throughout the history of such an object, and by reading of the typography of the land surrounding the object. At the contrast to the most used static modeling, there is a usual need of a set of data related directly with the objects in question which are either difficult to be local or need a lot of means to be effective. The approach of dynamic modeling can allow the modeling of geological objects having complex geometric forms (like granite, magma…), and the classification of another type of processes like the process of concentric foldsthat are more local than those of similar folds.

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