

Preserving Geological Information during Real-Time Editing of Faults in Tetrahedral Models

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ABSTRACT: Modelling underground physical processes with finite elements or finite differences methods requires volume meshes of the subsurface. Tetrahedral grids offer much greater geometric accuracy than Cartesian or curvilinear grids because cell sizes and shapes can adapt to complex geological features. In tetrahedral grids, faults can be modelled as topological discontinuities. Accounting for new information on fault geometry through a complete rebuild of the model is time-consuming. Instead, we present a tool which makes small geometric modifications to faults in tetrahedral models. Fault editing is performed without computing a new tessellation for the whole model, and in real-time so that feedback is immediate. If these modifications occur close to a fault contact, consistent fault contact geometry is maintained: the secondary fault moves along the main fault without going through it, and the overall shape of the main fault does not change. When the edited model contains geological properties, the rock properties attached to the points in the model are updated in order to maintain the spatial continuity of the property in each fault block and according to fault throw, and to maintain the conditioning to well or seismic data in the edited domain.

KEYWORDS: *tetrahedral model, fault geometry, real-time editing, fault contact.*

1. Introduction

Grid building remains a challenge in reservoir engineering. Geometric accuracy must be balanced against optimised use of computer resources. Generally, reservoirs are modelled as curvilinear grids – Cartesian grids in which cell layers are deformed to match horizon and fault geometry. But reservoirs can sometimes be so complex that a curvilinear grid does not reflect the geometry of layers and faults. With tetrahedral grids, mesh density and geometry can be adapted to the structures to be represented.

Accurately positioning faults in a geological model is a major concern for geologists. Incomplete and biased subsurface information make this task difficult. New information on faults has to be included in the models in order to improve their accuracy. Accounting for new information through a complete rebuild of the model is time-consuming. Instead, we present a tool to make small modifications to faults in tetrahedral models in order to accommodate changes of geometry according to new information or new interpretation of subsurface data. Such small editions are performed without having to compute a new tessellation for the whole model, and in real-time so that the feedback on editing is immediate.

2. Fault editing tool

2.1. Faults in tetrahedral models

Tetrahedral models in geology are divided into different fault blocks. Inside a fault block, tetrahedrons are all connected, and each tetrahedron shares vertexes and faces with its neighbours. A fault is modelled as a topological discontinuity in the volume. Tetrahedrons on both sides of a fault do not share faces and vertexes are duplicated. Fault editing requires modifying the geometry and possibly the topology of the tetrahedral mesh. The current way to

deal with this problem is to edit the structural model from which the tetrahedral model was constructed and build a new tetrahedral volume. The fault-editing tool presented here makes small adjustments to fault geometry in real-time. An editable volume around the fault is defined, and it is deformed by picking and dragging arbitrary control points. The deformation on the tetrahedral mesh is instantly visible, and editing is stopped when the new geometry is acceptable.

2.2. Fault editing

The fault editing tool was developed in a plug-in to the gocad software. One or more control points are created on the fault to be edited. A value of distance to the fault is chosen, thus determining the volume around the fault that will change geometry. A small value enables little changes on a part of the fault. A higher value enables general reshaping of the fault. The volume selection step is made easier by the visualisation tools developed by Frank (2006).

As a control point is dragged inside the control volume, a displacement vector is computed between the starting position of the control point and its current position. This vector provides displacement direction and magnitude. The magnitude of the displacement is interpolated on all tetrahedron vertexes inside the control volume by Discrete Smooth Interpolation (Mallet, 1992, 2002), from the value set by the control point to zero on the borders of the editable volume. Then the vertexes of the tetrahedral mesh that are inside the control volume are moved along the displacement direction, using the displacement magnitude computed for each vertex. Details of mathematical formulation and implementation can be found in Tertois (2005).

Editing is carried out by moving control points around in the selected control volume. When a control point is moved, the editing tool enters a loop in which the displacement magnitude is computed over the control volume and the geometry is updated, as shown in Figure 1.

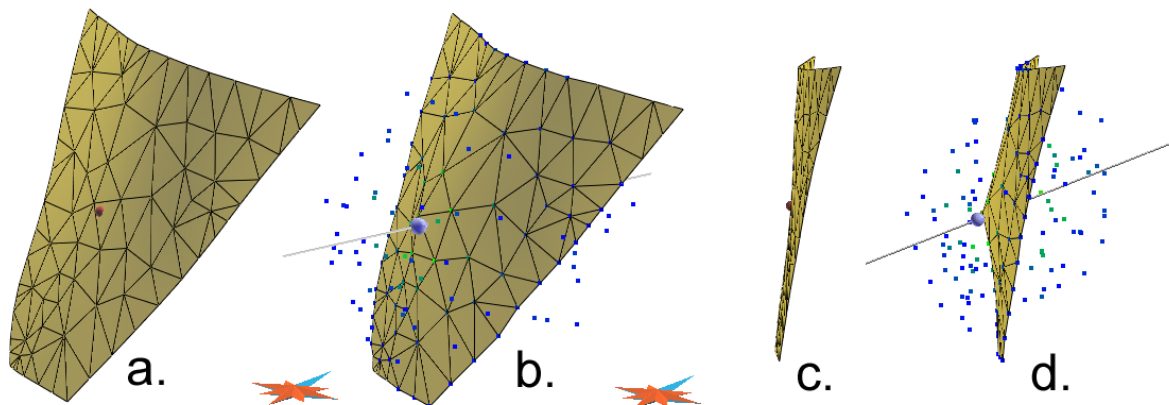


Fig. 1. Simple fault editing. a: Initial fault and control point. b: Control point is dragged on constraint line. Tetrahedron faces on fault and tetrahedron vertexes in control volume (blue and green) follow the movement of the control point. c-d: Fault editing from another angle.

3. Consistent editing of geological models

3.1. Editing fault contacts

When a control point is close to a fault contact, or even on the fault contact, additional constraints ensure that the shape of the main fault is preserved during editing. Fault contacts are detected automatically in an initialisation phase. If such a contact is found inside the editable volume, the normal to the main fault is interpolated as a vectorial property on the tetrahedron vertexes inside the editable volume. When the geometry update is performed, for each vertex, the component of the displacement vector which is collinear to the normal to the fault is removed. This ensures vertexes only move along the main fault, preserving the general

shape of the main fault while editing the secondary fault. Figure 2 shows an example of fault contact editing.

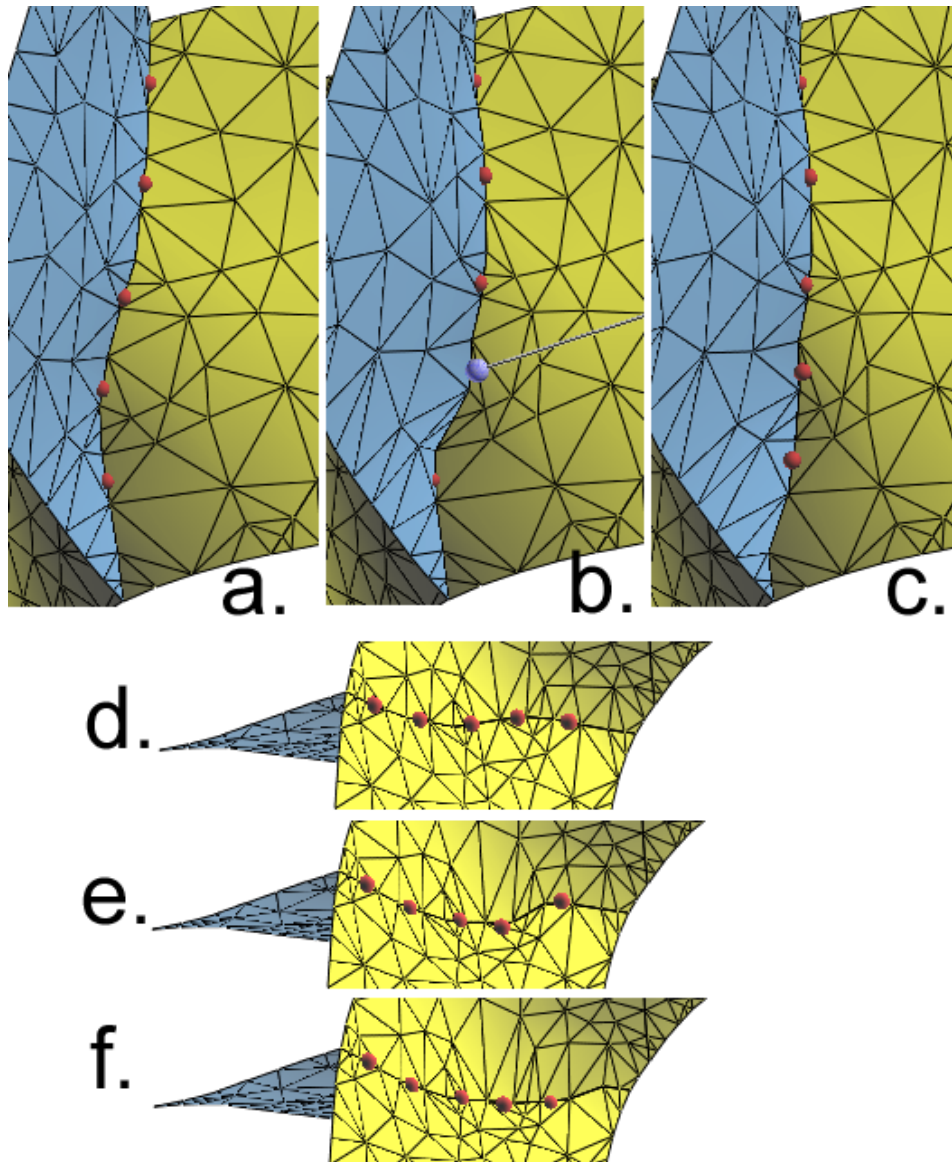


Fig. 2. Fault contact editing. a: Initial fault contact. The main fault is shown in yellow; the secondary fault is in blue. Five control points are set on fault contact. b: Dragging a control point. c: Fault contact after editing. The blue fault moved along the yellow fault. The general shape of the main fault did not change. d-f: Same editing steps from top view.

3.2. Three-dimensional property mapping

Texture coordinates define a three-dimensional mapping on the tetrahedral volume in the Geochron framework (Mallet 2004, Moyen 2005). Texture coordinates are attached to tetrahedron vertexes. If the geometry of these vertexes change, the texture coordinates are updated so that the mapping is not distorted. Before editing begins, the texture coordinates are copied to a background volume. As the vertexes in the editable volume move, their texture coordinates are retrieved from the background volume. Figure 3 shows results of fault editing in a Geochron model with mapped porosity simulation.

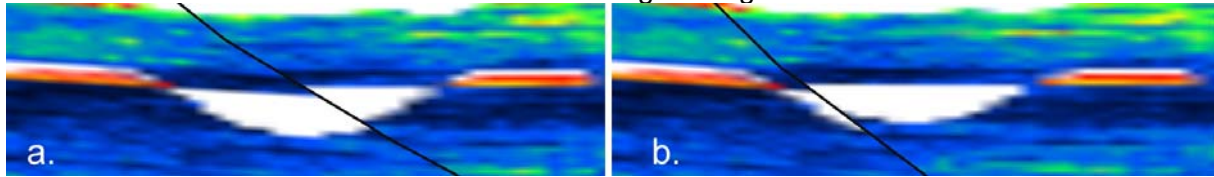


Fig. 3. Fault editing with texture-mapped porosity simulation. a. Initial texture mapping. The fault intersects a channel. b. Texture mapping after fault editing. The texture mapping was not warped when the tetrahedron vertices moved. Because texture coordinates are updated while editing, channel material was actually transferred from one side of the fault to the other.

4. Discussion and conclusions

The fault-editing tool presented in this paper enables direct geometry adjustments in real-time. The user can very precisely control the aspect of the mesh while editing, whereas existing FFD techniques usually involve control lattices or control curves. The tool provides fast enough graphic feedback to enable comfortable fault editing. The frame rate decreases when the editable volume expands, but a volume with about 700 nodes (about 4,200 tetrahedrons) can be edited in real-time on standard consumer hardware.

We presented in this paper a real-time fault editing tool for volume models. The user defines a deformable volume and control points, and drags the control points until the shape of the fault is satisfactory. The geometry of the model and its visualisation are updated in real-time. The magnitude of the editable volume and additional control points can be used to precisely specify which regions of the model can change, and which regions should not be modified.

In some cases, larger modifications have to be made to tetrahedral models. These changes cannot be made while keeping the same tessellation. The next step for fast model editing is to develop tools which enable topological changes in tetrahedral models without having to compute a new tessellation.

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