Grid Generation for Complex Geological Systems in Mining Areas

Kopp Andreas[1], **Sheta Hussam**
Dept. of Hydromechanics and Modelling of Hydrosystems, Universität Stuttgart,
Pfaffenwaldring 61, 70561 Stuttgart, Germany
[1] *Andreas.Kopp@iws.uni-stuttgart.de*

Abstract

This papers describes the process of discretising the highly complex underground in a mining area. Exhausted or non-exhausted coal seams, shafts, fractures and transport roads are found in addition to the natural geologic multi-layer system. The motivation to discretise and simulate this large-scale domain is to quantify methane gas migration in the sub-surface. Methane is released from coal seams as man-made shafts, transport roads etc. are built, causing a pressure drop to atmospheric conditions. The initially high methane source term declines over time. Different physical properties, like porosity and permeability are addressed to the coal seams and the surrounding rock matrix. The sub-surface geometry is constructed in the program RhinoCeros by McNeel. For grid generation, ICEM CFD by Ansys is used. Interfaces have been coded to import and export information between the programs which guarantee for conserved tolerances and no loss of accuracy. An application is presented, where a model of a real mining area has been built consisting of several hundreds of NURBS surfaces and several kilometres of transport roads based on geological maps.

Methods

As can be seen in Figure 1, two distinct workflows for model building from geometry construction to CFD simulation have been developed for the modelling system MUFTE-UG (cf. [1]). The first method is using AutoCAD & ART. AutoCAD (http://www.autodesk.com) is the well known CAD (Computer Aided Design) system by Autodesk corporation. ART (cf. [2]) is a proprietary development of the Universität Stuttgart and employs an optimised Delaunay-Triangulation method for 2D and 3D grid generation (including fractures).
The second method using RhinoCeros & ICEM CFD is used here because of the fast, efficient and exact geometry construction in RhinoCeros (http://www.rhino3d.com) and the robust and fast grid generation in ICEM CFD (http://www.ansys.com/products/icemcfd.asp). In the RhinoCeros CAD package, geometry is constructed in the boundary representation (BREP) format. In BREP format material points define domain properties in enclosed volumetric objects. Objects are approximated by Non-Uniform Rational B-

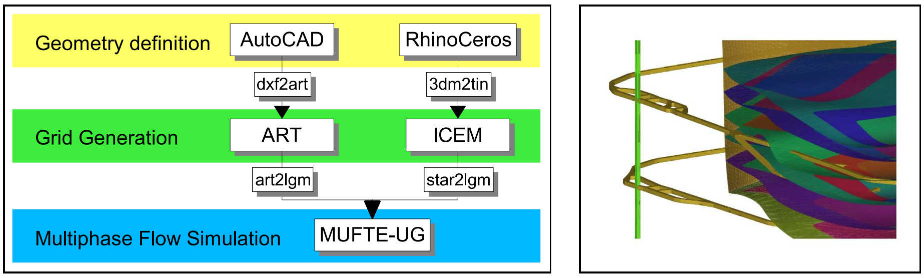

Figure 1: Left: Geometry definition and grid generation possibilities developed for the modelling-system MUFTE-UG. Right: Exhausted or non-exhausted coal seams, shafts, fractures and transport roads are found within the geologic multi-layer system.

Splines. ICEM CFD offers an octree method for unstructured 3D tetrahedral grid generation and patch-independent 2D tetra grid generation (besides hex, prism meshing etc.).

Workflow

First, an error-free CAD geometry has to be obtained. Coal seams are defined as 2D free form surfaces within a 3D surrounding matrix. Shafts and transport roads are modelled as 3D elements. Intersecting curves are then determined between all features. Each feature (coal-seam, transport road, etc.) gets solely repaired (i.e. checked for errors and 'water tightness' within a given tolerance) and surface meshed with the patch-independent tetra octree method. This is to determine appropriate edge lengths of tetras, respectively tetrahedrons, necessary for later volume meshing. A resulting surface mesh with its quality metric histogram and the transport road system can be seen in Figure 2. Finally, all features are put together and get volume meshed. The surface mesh is not used for volume meshing, only the determined tetra edge lengths settings are retained! A good quality, error free 3D tetrahedral mesh with several million nodes representing all features can thus be generated.

Acknowledgement

The author gratefully acknowledges the generous funding by the European Union Marie Curie Conferences and Training Courses fellowship (MSCF-CT-2004-013336).

References

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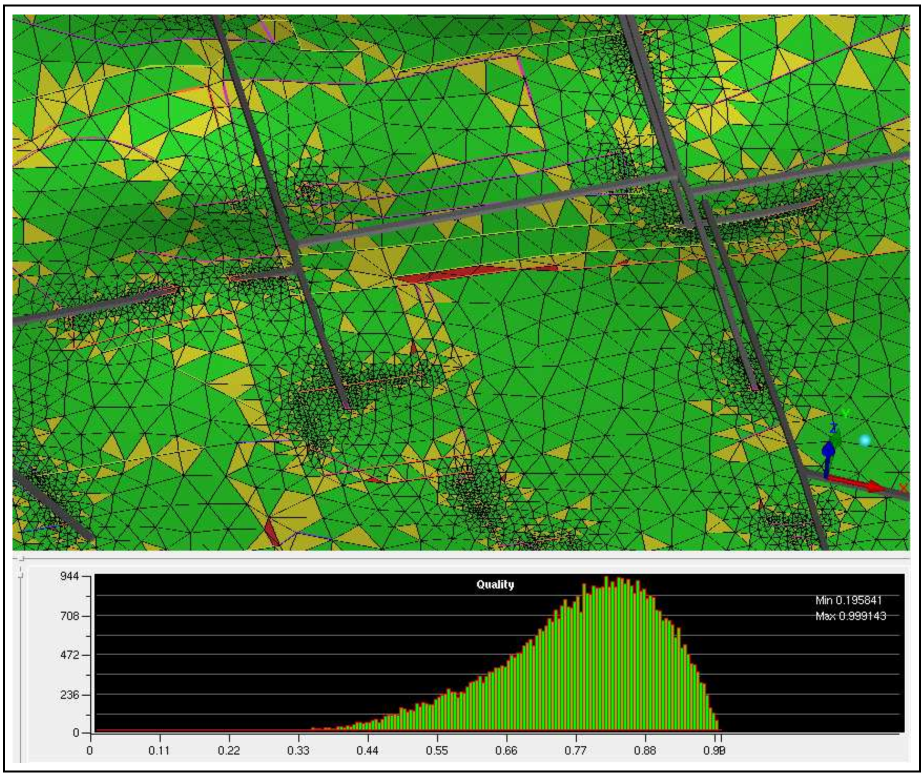

Figure 2:
Top: Top view on a surface grid of a selected non-flat coal seam intersected by transport roads (grey colour). Tetras are colour coded by quality. Green colour identifies best, yellow colour medium and red colour worst quality. Quality is calculated as the minimum ratio of height to base length of each side (normalised to 1).
Bottom: Quality metric histogram of the surface mesh. Minimum quality is 0.195. Quality metric can be considered as very good.