Optimal point positioning in polyhedral decomposition of subsurface fracture networks

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Profound knowledge of flow behaviour in subsurface fracture networks is crucial when it comes to planning petroleum production, geothermal energy production or radioactive waste disposal. For such topics discrete models of the fractures are required as the spatial distribution of processes is of interest. Consequently, the mesh serving as a basis for finite element simulations must represent complex geometries and must cope with both, the space-dependent character of the considered equations and the numerical requirements at the discontinuities. It must work on both lower-dimensional and equidimensional geometric models.

A mesh generation algorithm fulfilling all of those demands was developed and presented [1], [2]. Its basic idea is block decomposition which is a well-known method [3]. But here this method is altered in three ways. Firstly, blocks are separated with regard to identical requirements for the grid's dimension, density and structuredness, rather than geometric issues. Secondly, the resulting blocks are polyhedral, not purely hexahedral. Thirdly, the geometrical constraints are accounted for via an optimization scheme. These local geometrical constraints guarantee the absence of negative volume polyhedra and advance the shapeliness. They are expressed based on point-to-face distances, see figure 1. The latter are then maximized with the help of a Simplex algorithm that is applied recursively. The optimization scheme applied, both the constraints themselves and their algorithmic implementation will be the main focus of the talk.

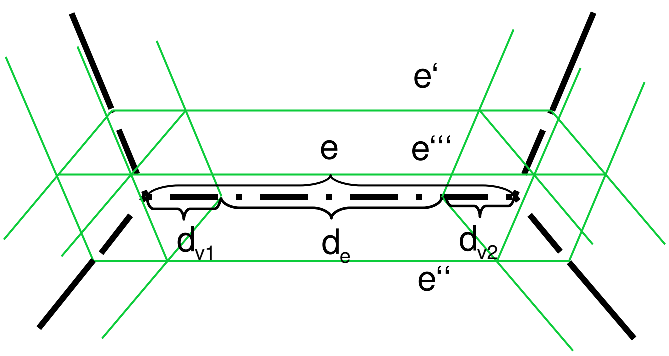

Fig. 1: Geometrical constraints arising for edge *i*

$$d^i_{\mathrm{v1}} + d^i_{\mathrm{e}} + d^i_{\mathrm{v2}} < \min\{e_i, e'_i, e''_i, e'''_i\}$$

The block decomposition does not only serve as a first step of the grid generation but also as geometric modelling as the blocks that constitute the model can be chosen flexibly: In addition to the 3D model and the 2.5D model we also offer a 2.75D model, see [2] for a first version.

Finally, a range of case studies shows promising results: 2.75D modelling is a solution for field scale heat transport simulations, where 2.5D fails and 3D charges cpu. It also improves the simulation in fracture networks containing dead end structures. Furthermore, the approach being based on a topology analysis offers the meshing of dolerite dykes as an example of even more complex polyhedrally bounded geometries.

[1] S. Moenickes, T. Taniguchi, R. Kaiser, W. Zielke, "Meshing Strategies for FEM Simulations in 3D Fracture Network Systems", In Computational Mathematics and Mathematical Physics, 6: 854 – 862, 2003

[2] S. Moenickes, T. Taniguchi, "2.75D FE Model of 3D Fracture Network Systems", Proceedings 11th IMR, 2002.

[3] T. Tam, C. Armstrong, "Finite element mesh control by integer programming", Int.JNMEng., v. 36, 1993.