Using Gmsh with MRST

August Johansson
SINTEF Digital, Oslo, Norway

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Gmsh

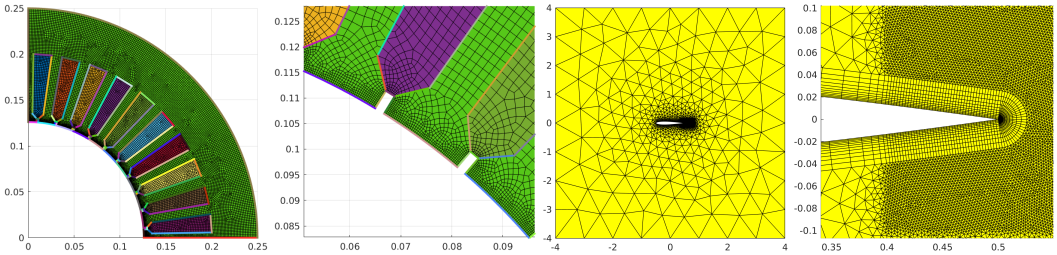
In short, Gmsh is

- A geometry modeling software with CAD engine (OpenCascade).
- A mesh generator.
- See `http://gmsh.info`

Can it be useful for the the MRST community? It seems so:

- Mature code with large community and many examples.
- Well established (15k downloads per month, 700 citations per year).
- Multiple interfaces:
  - GUI
  - Scripting language (`.geo` files)
  - API (C/C++, Python or Julia)
- Much used in the open source finite element community, but also in open source geology modeling softwares. For example:
  - Frackit, a software for stochastic generation of fracture networks (Helmig et al)
  - Gempy, a geomodeling library (Gmsh support in progress).

Many examples are provided with Gmsh



Left: A quarter of a stator with multiple labelled subdomains and labelled edges.
Right: A NACA 12 airfoil modelled by a triangular/quadrilateral grid with boundary layer.

These are MRST grids.

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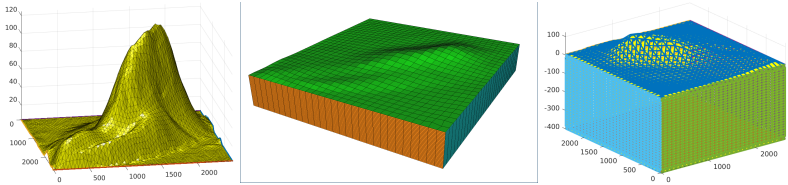
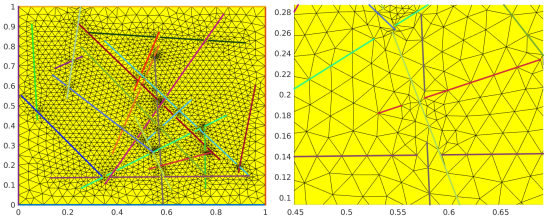
Using Gmsh with MRST

1. Use the interfaces (GUI, scripting or API), or external program (Frackit), to construct a model (a `.geo` file or object). This contains:
   - Geometric model with labels of entities (points, edges, faces, subdomains…).
   - Specification of the mesh (mesh size, element types, which mesh generator to use etc).
2. Create a mesh in the native `.msh` format using the GUI, API or command line.
3. Convert to MRST grid format using the python script `gmsh_to_mrst.py`:
   ```
   $ python gmsh_to_mrst.py my_model.msh my_model.mat
   ```
   The script is available at `https://github.com/augustjohansson/gmsh_to_mrst`
4. Load ‘.mat‘ file in MRST.
   ```
   » G=load('my_model.mat');
   ```

More examples



Left: STL triangulation from point cloud. *Middle*: Hexahedral mesh approximating point cloud surface. *Right*: MRST grid (script bug: face orientation is not correct).



Domain with crossing fractures. Gmsh is not able to respect the fractures if one naively embed all the fracture curves. (How does Frackit implement crossing fractures?)

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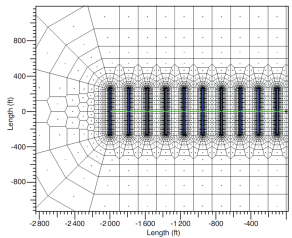
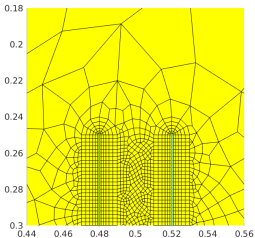
More Gmsh cons

- Not polytopic elements
  - 2D: triangles, quads
  - 3D: hexahedra, tetrahedra, pyramids and prisms.
- Built-in routines for boundary layer meshing perhaps not as capable as eg. KAPPA. In Gmsh, manually adding constraining points are probably needed. Perhaps this can be done with a custom plugin.





Left: Mesh from KAPPA with multiple structured boundary layers (figure from Artus, Fructus. OGST 67(5)). Right: Similar example using Gmsh with automatic boundary layer and fan around two 1D fractures.

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Conclusions

- Gmsh works well, but not in all situations (for example, for multiple intersecting fractures, one must split the fractures at the fracture–fracture intersections manually).
- There is missing desired functionality regarding boundary layers around fractures touching the boundary (issue on Gmsh git page).

TODO:

- Fix face orientation for 3D elements.
- Respect Gmsh's "Physical Labels".
- Use Gmsh as an alternative to Distmesh as backend for the MRST modules UPR (Berge et al) and NWM (Zhao).

Collaborations most welcome!

References 1

- Gmsh: `https://gmsh.info`
  - Geuzaine and Remacle (2009). Gmsh: a three-dimensional finite element mesh generator with built-in pre- and post-processing facilities. Int J Numer Meth Eng 79(11).
- Gempy: `https://gempy.org`
  - de la Varga et al (2019). GemPy 1.0: open-source stochastic geological modeling and inversion, Geosci. Model Dev., 12.
- Frackit: `https://git.iws.uni-stuttgart.de/tools/frackit`
  - Gläser, D., Flemisch, B., Class, H. and Helmig, R., (2020). Frackit: a framework for stochastic fracture network generation and analysis. J Open Source Softw, 5(56).
- UPR: `https://github.com/rbe051/UPR`
  - Berge, R.L., Klemetsdal, Ø.S. & Lie, K-A. Comput Geosci (2019) 23: 169.
- NWM: Near-wellbore modeling `https://bitbucket.org/LinZhao9/nwm` (Zhao, L).
- KAPPA: `https://www.kappaeng.com/`
  - Structured mesh image from: Artus, V., Fructus, D.: Transmissibility Corrections and Grid Control for Shale Gas Numerical Simulation. Oil Gas Sci. Technol. Rev 67(5).
- Distmesh: `http://persson.berkeley.edu/distmesh/`
- Gmsh-to-MRST: `https://github.com/augustjohansson/gmsh_to_mrst`

Other relevant projects

- RRM: Rapid reservoir model: `https://rapidreservoir.org/`
  - `https://bitbucket.org/rapidreservoirmodelling/rrm/`
  - Sketch-based interface and modelling of stratigraphy and structure in three dimensions. C. Jacquemyn et al. J Geol Soc (2021) 178 (4): jgs2020-187.
- CGAL: `https://www.cgal.org/`
  - Can create Voronoi diagrams.