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Making sense of Isogeometric Analysis for geothermal applications: Parametric geomodelling (NURBS) for fast model construction, simulation and adaptation

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Geological modelling is an essential aspect of a wide variety of geophysical and geological investigations related to geo-energy exploration and monitoring. A commonly-applied procedure is to use 3D geological models (often referred to as static models) to characterise the spatial distribution of material properties, which are then used in subsequent process simulations. The physical processes are described with partial differential equations that can be solved using different numerical methods by creating a discretisation in the space of the geometric object (i.e., a mesh). However, mesh generation can be a time-consuming step that generally only allows an approximation of the true geometric model. Several methods have been proposed to resolve these issues. We investigate here the use of the isogeometric analysis (IGA) technique, which exploits the finite element method (FEM) to numerically solve differential equations without the need of creating a mesh. Instead, it uses computer-aided design (CAD) tools, specifically Non-Uniform Rational B-splines (NURBS), to accurately represent any form of conic sections geometry.

This presentation shows the link between NURBS representing geological interfaces and subsequent geothermal process simulations. The link is implemented in a user-friendly Python package (https://github.com/danielsk78/pygeoiga) with a simple but clear interface. It differs from other implementations by dealing with multipatch structures and focusing on geological modelling with multiple subdomains. A series of numerical examples are presented to show the use of the technique for solving the two-dimensional heat conduction problem. Results are contrasted to the results of a traditional FEM approach. The comparison shows that IGA requires fewer degrees of freedom (DoF) for convergence of the solution. Further, IGA provides a way to ease the workflow from the geological modelling to the results of process simulations, enabling tighter integration between modelling and simulation. Lastly, we describe shortly how the IGA concept can be implemented on top of existing standard FEM libraries.