Semi-structured multigrid method for fast numerical simulation of porous media flow

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This project will develop a semi-structured multigrid solver within the Imperial College Finite Element Reservoir Simulator (IC-FERST). IC-FERST incorporates state-of-the-art technology for porous media flow simulation, including unstructured dynamic mesh optimisation, high order element methods and surface-based representation of complex reservoir architectures. Applications of IC-FERST are numerous and include simulation of CO2 sequestration, hydrocarbon recovery (including improved and enhanced recovery), groundwater flow, contaminant transport and magma flow and eruption.

Currently IC-FERST uses adaptive, unstructured meshes. Flexible meshing technology is required in order to honour the complex geological geometries found in subsurface reservoirs (e.g. Fig. 1). However, numerical simulations using unstructured meshes are inherently slower than those using structured meshes due to the indirect addressing required by the former. This is partly compensated in IC-FERST by using dynamic adaptive mesh optimisation which reduces the number of elements whilst maintaining sufficient resolution to correctly model the physics.

In high performance computing, efficient numerical algorithms are essential to solve the large linear systems arising from the discretisation of the governing partial differential equations. Multigrid methods are amongst the most efficient algorithms. Currently, IC-FERST uses algebraic multigrid methods implemented in PETSc which admit complex meshes but at higher computational cost. Geometric multigrid methods allow much faster simulations but require less complex meshes.

This project will develop a fully parallelised, semi-structured multigrid solver for IC-FERST based on the PETSc library. In a semi-structured, multigrid solver, an initial unstructured coarse mesh is created to represent a complex geometry; next, a hierarchy of meshes is obtained by a refine-by-splitting process in each of the initial coarse mesh elements. In this way, a set of structured meshes is obtained in which a geometric multigrid, with its associated speed can be implemented.

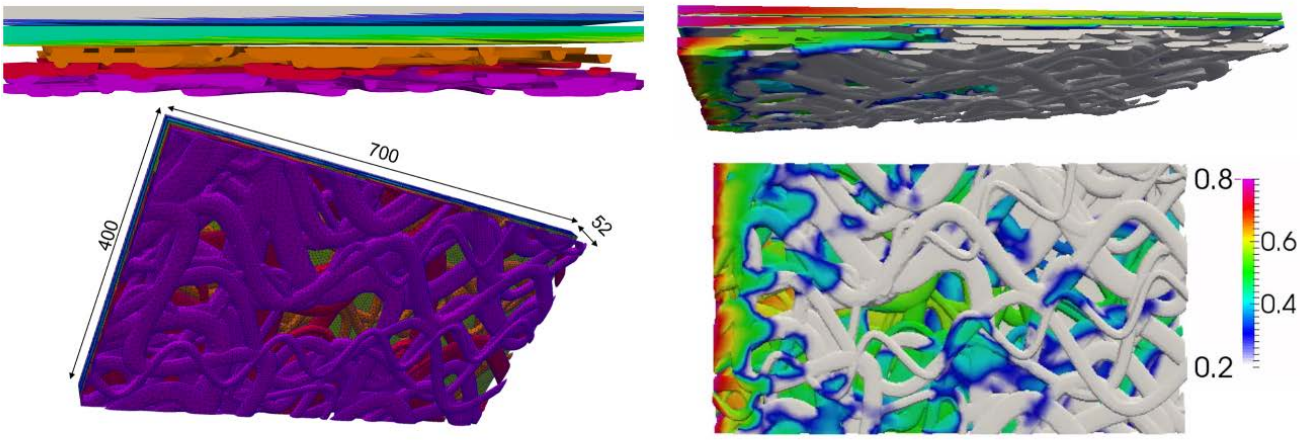

Fig 1 : Top left figure shows the permeability map of a complex reservoir model. Bottom left figure shows the channel system of the reservoir from below. Top right and bottom right figure display the saturation field at different times seen from the side-below and from below, respectively.

Applicants should have a strong mathematical background, a good degree in an appropriate subject (e.g. earth science, mathematics, physics, computer science or engineering) and a strong interest in computational modelling and code development. The project is hosted by the large and highly successful NOvel Reservoir Modelling and Simulation (NORMS) group and will involve extensive interactions with other groups within the Department and internationally. Skills developed during this project will include multiphase porous media flows, high performance computing, parallelisation of numerical codes, numerical discretisation techniques, linear and non-linear solvers, dynamic mesh optimisation techniques, and structured and unstructured meshing technologies. The candidate will develop their career and profile by presenting at conferences and publishing in high impact journals.

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