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Dynamic mesh optimisation for efficient density-driven flow simulations

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Density-driven flows in porous media are frequently encountered in natural systems and arise from the gravitational instabilities introduced by fluid density gradients. They have significant economic and environmental impacts, and numerical modelling is often used to predict the behaviour of these flows for risk assessment, reservoir characterisation or management. However, modelling density-driven flow in porous media is very challenging due to the nonlinear coupling between flow and transport equations, the large domains of interest and the wide range of time and space scales involved. Solving this type of problem numerically using a fixed mesh can be prohibitively expensive. Here, we apply a dynamic mesh optimisation (DMO) technique along with a control-volume-finite element method to simulate density-driven flows. DMO allows the mesh resolution and geometry to vary during a simulation to minimize an error metric for one or more solution fields of interest, refining where needed and coarsening elsewhere. We apply DMO to the Elder problem for several Rayleigh numbers. We demonstrate that DMO accurately reproduces the unique two-dimensional (2D) solutions for low Rayleigh number cases at significantly lower computational cost compared to an equivalent fixed mesh, with speedup of order x16. For unstable high Rayleigh number cases, multiple steady-state solutions exist, and we show that they are all captured by our approach with high accuracy and significantly reduced computational cost, with speedup of order x6. The lower computational cost of simulations using DMO allows extension of the high Rayleigh number case to a three-dimensional (3D) configuration and we demonstrate new steady-state solutions that have not been observed previously. Finally, applications of the present numerical framework to real-scale copper-rich fluid flow transport in sedimentary basins are considered.

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Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

In person

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