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Advances in three-dimensional, finite-element based marker-in-cell methods applied to geodynamics

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The use of a mixed finite element formulation to discretise Stokes equations, coupled with a particle based Lagrangian representation of the material lithology, is a common numerical technique employed within the Earth sciences to study geodynamic processes. The extension of this methodology to study high-resolution, three-dimensional problems, even in 2012, still represents a number of significant computational challenges. Of paramount concern are the high computational memory requirements, and the development of efficient and robust linear and non-linear solvers, which are performant on massively parallel supercomputers.

In this presentation, I describe a flexible methodology, which aims to rectify both of these issues. The key to the approach is to 1) always pose the discrete problem in defect-correction form and 2) utilise a mixture of assembled and matrix-free operations to evaluate the non-linear residual, and the operators required to define the multilevel preconditioner for the Jacobian.

The performance characteristics of the hybrid matrix-free, partially assembled multilevel preconditioning strategy is demonstrated by considering several variable viscosity Stokes problems employing the mixed element types Q2-P1 and Q1-Q1 (Bochev stabilisation). The robustness of the preconditioner with respect to the viscosity contrast and the topology of the viscosity field, together with the parallel scalability will be discussed.