Anisotropic mesh adaptation with Pragmatic and Firedrake

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1 Outline

This work builds upon a long track record in the development and application of anisotropic mesh adaptation technology at Imperial College London. Mesh adaptation involves generating meshes whose resolution and elements orientation are optimised to improve the accuracy of a simulation while reducing the number of degrees of freedom. This allows the mesh to evolve with the solution at run time. This results in significant savings in computational cost - particularly for multi-scale simulations. Most of this effort has so far occurred in the legacy Fortran code Fluidity.

More recently, a new open source remeshing library was developed at Imperial College London, Pragmatic, that generates an adapted mesh given an input mesh and an error measure. This library was devised from scratch to be parallel and HPC ready.

The overall aim of this project is to make use of the Pragmatic library to provide anisotropic mesh adaptation capabilities in PETSc, in order to enable this capability in modern parallel codes using this scientific library such as Firedrake. This will call for the integration of Pragmatic into PETSc unstructured mesh management library, DMPlex, and several improvements to Pragmatic to make it generate better quality meshes in an HPC context.

Mesh adaptation is a widely used technique in numerical simulation, particularly for multi-scale simulations, and the integration of Pragmatic in PETSc will make it within easy reach for the whole community of PETSc users (more than 10,000 results in Google Scholar). In particular, it will impact the community of Firedrake users (40 attendees from 12 research groups all over the UK and Europe at the Firedrake '17 meeting). At Imperial College London, in a context of migrating from legacy codes to Firedrake, there is an important need for this new feature. Several ongoing application areas will take advantage of it, notably inundation modelling, in the context of tsunamis and storm surges, in link with EPSCRC grant EP/M011054/1.

The goal of this project is to develop a prototype of this integration : a full adaptation loop will be implemented for a 3D advection problem and a 2D shallow water problem using Firedrake, based on a prototype of integration of Pragmatic into PETSc. This preliminary work will demonstrate the feasibility of the project, and help us understand the work to be done to extend it.

2 Alignment with PRISM strategy

Retention of key staff : This provides bridge funding for Dr Nicolas Barral. He has a strong background in mesh adaptive simulations and is an experienced PETSc developer. These skills will be required in many of the simulation tools being developed within PRISM.

Collaboration with other PRISM projects This work will make use of the Firedrake software environment and involve collaboration with their developers from the maths and computing departments.

Longer-term research : The aim of this project is to lay the foundations of anisotropic mesh adaptation for application codes using Firedrake. Ultimately, codes such as Thetis will benefit from the techniques implemented to increase their performance.