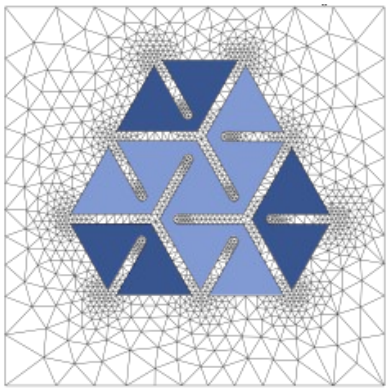
Inter-operability framework implementation of the high-order mesh generator Nekmesh



Personnel: Mashy Green (6 Months)

Collaborators: Joaquim Peiro, David Moxey, Spencer Sherwin, Peter Vincent (Aeronautics)

1. Outline

Nekmesh is a mesh generator that transforms a mesh of straight-sided elements into a high-order mesh that conforms to the boundary of the computational domain represented by CAD entities. The transformation is obtained through the minimization of a suitable “energy” functional that permits the correction and improvement of the quality of the elements. The meshes can be used by the PRISM open-source codes *Nektar++* and *pyFR*. The optimization algorithm employed allows for a very efficient parallel implementation: the current version is implemented in a multi-thread architecture and achieves scaling close to linear in most cases.

2. Objective

We propose to investigate the feasibility of software development inter-operability frameworks (IOF), such as *kokkos* [1] or *OpenACC* [2], to simplify the development and sustainability of the code *Nekmesh*. This will be carried out in line with previous work supported by PRISM on the use of collective linear algebra operations as performance accelerators for *Nektar++* [1].

3. Alignment with PRISM strategy

Retention of key staff. Mashy Green has submitted his PhD on “Modelling of sloshing using SPH”. He has developed a SPH code on GPUs using the CUDA programming language. His expertise on GPU architectures and programming will be instrumental to the successful completion of this project. This funding will also provide bridging funds for Mashy until further research funding is available.

Collaboration within PRISM. This work will involve collaboration with Dave Moxey, currently supported by PRISM. A successful outcome of the project will benefit current and future developments in *Nektar++* and *pyFR*. We also envisage potential interactions with *FireDrake* and *Fluidity* to help them address some of the difficult issues related to CAD interaction and high-order meshing.

Long-term research. We anticipate that the experience gained and any lessons learnt within this project will be of direct application to the more complex setting of codes such as *Nektar++* (and others).

4. Workplan

The main tasks within the proposed work are:

1. Appraisal of the suitability of IOFs, such as *kokkos* [1] and *OpenACC* [2], for the implementation of performance accelerators in heterogeneous architectures.
2. Development of a version of *Nekmesh* for the chosen IOF. This will require the re-appraisal of memory management and data structures currently used with CPUs to account for memory restrictions of GPUs.
3. Performance assessment of *Nekmesh* in both homo- and hetero-geneous architectures.
4. Transliteration of collective linear algebra operations to the chosen IOF.
5. Investigation of load balancing within heterogeneous multi-threaded CPU and multi-GPU architectures.

5. References

[1] The Trilinos Project, https://trilinos.org/packages/kokkos/
[2] http://www.openacc.org/
[3] D. Moxey et al., “Optimizing the performance of the spectral/hp element method with collective linear algebra operations, Comp. Meth. Appl. Mech. Eng. **310**, 628-645 (2016).