Implementation of parallel Arnoldi solver and cylindrical coordinates in Nektar++

Duration: 3 months, Researcher: Gabriele Rocco

Outline: Nektar++ is a high order spectral/hp element code with primary solvers developed for fluid mechanics simulations. The code has an incompressible solver based around a velocity-correction algorithm as well as a compressible flow solver based on explicit DG and more recently Flux Reconstruction methods. The focus on this project is the extension of features related to the incompressible solver but which have potential extensions to other solvers in this framework.

Project objectives: The project is to help capitalize on the expertise of Garbiele Rocco who has submitted his PhD thesis on stability analysis of flows using the Nektar++ incompressible flow solver. Whilst a number of developments have been contributed to Nektar++ during his PhD work he was unable to complete two interesting features which were not required to complete his PhD thesis but would be valuable within the framework. He is currently in a desirable position of having extensive knowledge of the framework and can therefore relatively easily implement the proposed extensions in 3 month project.

Parallel Arnoldi solver: To perform stability analysis of the linearized Navier-Stokes equations we have a wrapper/driver calling an Arnoldi solver as well as the well known package Arpack. The internal solver is simpler to distribute and typically provides better run time diagnostics. We however need a parallel version of this implementation for larger 3D stability analysis problems. The initial implementation has been done but it still requires extensive debugging and validating.

Cylindrical coordinate solver: During an earlier part of his PhD work we considered using a cylindrical coordinate system to solve flows within a jet problems. An axisymmetric elliptic solver was implemented within a branch of the code but was never integrated into the master. To enable future work on this convenient coordinate system for specialized problem we would like to see this code fully tested and integrated into the Master branch. Depending on how well the other developments go this solver would also be applied to the Incompressible Navier-Stokes and possibly extended to 3D using a Fourier expansion.

Alignment with Prism strategy:

- *Development of key staff*: Although Gabriele ultimately wishes to gain experience outside of his PhD work and so find a position in another institute, he is in an excellent position to aid the development of the Nektar++ framework through this short project. This necessarily will not only improve the framework through utilizing the previous knowledge gained during his PhD studies but will also allow him to promote these techniques to the broader PRISM group and thereby potentially help promote wider collaboration.
- *Collaboration other PRISM projects:* Research with Colin Cotter on a joint project of evaluating steady state solutions for stability analysis will benefit from the parallel eigensolver development.
- *Longer-term research*: Being able to perform large-scale parallel eigenproblem and cylindrical coordinate system problems opens up the capability to perform triglobal/3D staibility analysis and also efficiently solve problems where a cylindrical coordinate system is appropriate. In the longer term we also plan to be able to use these features with other solvers and the design of this code is such that the “driver” function wraps all solvers and so will be directly available.

Brief Work Plan: There is no need for any background work in the project. Most of the complexity will be involved in code debugging and validation testing. The initial stage of the project will require updating all codes to the current master. Then a small amount of restructuring will be required for the cylindrical coordinate sub-project. The bulk of the time will be required for testing and validation of both objectives and a project report will be provided detailing the work undertaken with all user operation being placed on the Nektar++ wiki. If additional time is available this will be focused on establishing a 3D Spectral/hp element based Navier-Stokes solver in cylindrical coordinates. A presentation on his work will be made to the PRISM post-doc group.