NekMesh: towards industrial high-order mesh generation

August 15, 2019

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1 Outline

High-order methods have increasingly received attention from the Computational Fluid Dynamics (CFD) community for their ability to run scale-resolving simulations. Large code platforms have emerged, covering a broad range of physics. Two examples of such open-source CFD codes are currently being developed within PRISM: *Nektar++*, based on the spectral/*hp* element method; and PyFR, based on flux reconstruction and targeted at High-Performance Computing (HPC) hardware. Benefits of the approach include low dispersion and diffusion error and spectral convergence of the solution. However, a geometrically-accurate discretisation of domains is necessary to achieve a spectral rate of convergence towards the true solution.

Mesh generation, especially *high-order*, remains a bottleneck for the CFD community with requirements such as model size and complexity increasing year after year. Our code, *NekMesh*, has been developed with focus on generating quality high-order meshes for complex three-dimensional geometries. We propose to improve the robustness of *NekMesh* and make it more readily accessible to the PRISM and wider academic and industrial community.

2 Objectives

Like many academic codes, *NekMesh* has shown impressive academic results through publications but lacks the robustness sought after by the industrial community. To this purpose, a collaboration with ITI Global during my doctoral studies has focused on integrating a commercial Computer-Aided Design (CAD) system and linear mesh generator in *NekMesh*. This allowed us to more robustly generate geometrically-accurate high-order meshes around complex industrially relevant geometries. This work, however, did not utilise all the capabilities of *NekMesh*. One important component of *NekMesh* is its variational optimiser of high-order nodes. Improving the robustness of the optimiser, supported by a robust CAD system and linear mesh generator, will constitute an important step towards the industrial use of high-order mesh generation and CFD solvers. Focus must then be placed on disseminating these developments and establishing *NekMesh* as a key piece of software in the high-order mesh generation community.

To fulfill this goal, we identify two areas where work is needed:

- **Functionalities:** Improvement of the robustness of core features of *NekMesh*, in particular the variational optimiser and the interfacing code, is essential, in addition of the continued collaboration with ITI Global on novel features. Following these vital improvements, extensive testing will be required and we propose to generate meshes for increasingly complex geometries and, eventually, run simulations on them.
- **Dissemination:** *NekMesh* needs to be made

easier to use. A release of the software will be made available to the community, independent from *Nektar++*, following the improvement of the package generation procedure. This will improve the visibility of the software along with improved user documentation and additional publications on both the release version of the code and the new features and capabilities.

3 Alignment with PRISM strategy

- **Retention of key knowledge:** Following the departure of Michael Turner from the *Nektar++* development group, I am now the main developer working on *NekMesh*, with the external support of Dr. David Moxey. The continuation of my funding will allow to bridge the gap until new personnel is found to continue development of the high-order mesh generation platform. In the event that no new developer is found before this bridge funding expires, every effort will be made to document *NekMesh* to the largest extent possible. Extensive documentation will make it possible for future researchers to easily pick up the development of the code to pursue the long-term research objectives of the broader *Nektar++* group.

- **Long-term research objectives:** The proposed work will support current *Nektar++* users in generating quality high-order meshes for their CFD applications. The development of *NekMesh* naturally benefits the broader *Nektar++* group. This project will also allow me to further establish myself in the high-order mesh generation community and *NekMesh* as a key piece of mesh generation software.

- **Integration within PRISM:** Dr. Peter Vincent, another investigator within PRISM, leads the development of PyFR. As with all high-order codes, PyFR requires high-order meshes to achieve spectrally accurate results. We propose to investigate the use of *NekMesh*-generated meshes within PyFR.

4 Workplan

- Merge all Work-In-Progress (WIP) branches, related to both new features and robustness improvements, into the master branch.

- Investigate the robustness and efficiency of the variational optimiser. Anticipated targets include: core formulation parameters, parallelisation and user inputs.

- Improve and expand regression tests for facilitated future developments.

- Generate meshes of complex three-dimensional geometries and obtain high-order flow solutions on them.

- Improve the packaging of the code and create an independent release of *NekMesh*.

- Expand the user guide for easier entry by new users.

- Demonstrate the developments above through publications in *Computer Physics Communications* and other relevant journals.