Stabilized finite element fluid flow modeling with correct energy dissipation

There is an opportunity for M.Sc. graduation work within the ship hydrodynamics group of 3ME.

Project background

When solving fluid flow problems with either Finite elements or its extension Isogeometric analysis the hyperbolic nature of the problem possess challenges. One popular approach is to use a stabilized formulation. In this approach the standard Galerkin formulation is replaced with a Petrov-Galerkin formulation. The Variational-Multiscale (VMS) method justifies this from a more physical perspective and provides a framework for devising alternative methods.

One such avenue is to design stabilized methods that have a provable energy dissipation. In [1] and [2] the VMS is used to construct such a method. However, in this method the correct energy behavior comes at the price of an additional variable each primary variable. This can be seen as a Lagrange Multiplier on the VMS modeling. Each additional variable also adds a coupled PDE to make the system of equations solvable.

In [1] and [2] VMS arguments justifies to modify the VMS method to the GLS method which allows the elimination of some of the additional variables. However, form a computational and implementational point of view the question arises whether it is possible to get rid of the auxiliary variables altogether while still having the correct energy behavior.

[1] M.F.P. ten Eikelder and I. Akkerman. Correct energy evolution of stabilized formulations: The relation between VMS, SUPG and GLS via dynamic orthogonal small–scales. I: The convective–diffusive context. CMAME 331:259–280, 2018.

[2] M.F.P. ten Eikelder and I. Akkerman. Correct energy evolution of stabilized formulations: The relation between VMS, SUPG and GLS via dynamic orthogonal small–scales. II: The incompressible Navier–Stokes equations. CMAME, 340:1135-1159, 2018.

Tasks

Develop, implement, verify and assess an alternative VMS approach with a correct energy dissipation without additional global variables. The implementation will be done in the opensource software package MFEM.

Whats in it for you

You will gain experience in programming in C++ using a generic finite element software stack. This software is suitable of extremely large scale simulations (100k cores) and has NURBS-based Isogeometric Analysis capability. You will learn the ins and outs of Variational-Multiscale method, which is a versatile simulation/modeling approach. Both IGA and VMS are bleeding edge methods at the for front of current computational research.

Contact

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