Stabilized and Multiscale Isogeometric Collocation Methods for Transport and Incompressible Turbulent Flow

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ABSTRACT

Collocation has recently arisen as a powerful alternative to Galerkin's method in the context of isogeometric analysis. In particular, isogeometric collocation exhibits a strongly reduced computational cost when compared with comparable Galerkin approaches while maintaining higher-order convergence rates. While isogeometric collocation has proven to be a powerful technique in many application areas including structural dynamics and phase-field modeling, its use in the context of fluid flow and transport is still relatively unexplored.

In this talk, we discuss simulation of transport and fluid flow phenomena using isogeometric collocation and demonstrate that standard approaches are generally deficient in that they (i) produce solutions that exhibit spurious oscillations in the advection-dominated setting and (ii) do not produce inf-sup stable methodologies for incompressible flow problems. We propose fixes for these two issues by introducing "stabilization" mechanisms inspired by concepts arising in the stabilized methods community. In particular, we look at the use of algebraic subgrid-scale models and residual-based eddy viscosity models. We demonstrate through numerical example that the aforementioned fixes do indeed yield robust and accurate stabilized isogeometric collocation methods, and we further demonstrate that the fixes do not significantly increase the computational cost of the standard isogeometric collocation method.

We finish this talk by demonstrating that the aforementioned stabilization methodologies may also be employed within a residual-based variational multiscale large eddy simulation framework for turbulent flows. This yields a turbulence simulation technology that inherits the consistency and stability of the standard residual-based isogeometric variational multiscale approach but at a fraction of the cost. We demonstrate the effectiveness of this new large eddy simulation technology using two canonical turbulence benchmark problems, forced homogeneous isotropic turbulence and turbulent channel flow.