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Master thesis

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Optimal Stabilization and Time Step Constraints for the Explicit/Implicit Discontinuous Galerkin Method Applied to Elliptic Equations

Discontinuous Galerkin (DG) is a class of finite element methods that has gained a lot of popularity over the last two decades [1]. The method has known a remarkably vigorous development, as suggested in Figure 1, where we display the number of papers (in the American Mathematical Society database MathSciNet) whose title contains the words discontinuous Galerkin.

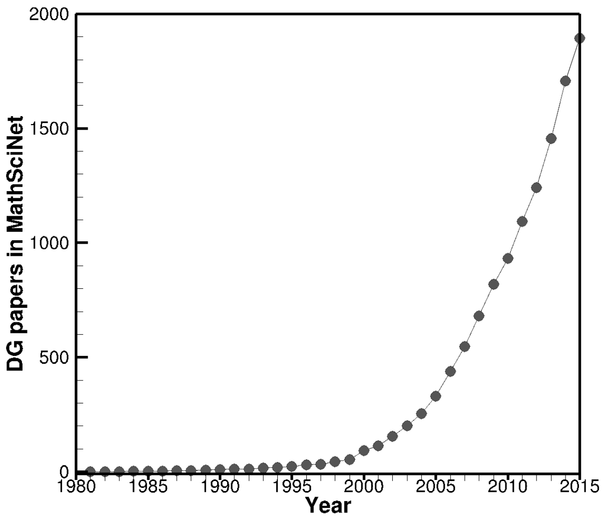

Figure 1: Cumulative number of papers containing the words discontinuous Galerkin in their title.

DG discretization is attractive because it has several advantages, such as lower dispersion, more natural treatment of the convective operators, the higher extending potential for higher-order discretization, higher parallelization capacity, and better h/p refinement capability. Therefore, DG could be a very good method of choice for higher-order discretization of Navier-Stokes equations on arbitrary unstructured meshes. While DG methods seem to be well suited for the discretization of hyperbolic problems, their extension to the elliptic equation is far less obvious.

Most methods for the discretization of elliptic problems depend on penalty terms. These stabilization terms are not suitable for time advancing explicit/implicit schemes since they are limited by a severe time constraint. So the penalty terms play a critical role to achieve high convergence rates in explicit/implicit methods. This thesis focus on optimal rates of convergence for the proposed penalization.

Within the scope of this thesis, the student should study and implement different schemes for discretization second-order equations (such as the local discontinuous Galerkin [2] and the compact discontinuous Galerkin [3]). The relationship between the stabilization term, method parameters and the convergence rates in theses schemes will be analyzed and discussed. Finally, he or she should indicate the optimal rates of convergence and time step with respect to the proposed penalization term for two-dimensional problems at different degrees and flow regimes.

Required knowledge includes an interest in mathematical modeling, finite element method (preferably one has taken the DG class at IBNM) and scientific computing. In addition, programming skills with a background in discretization methods are required. This thesis will be supervised in English.

Literature:

[1] D.E. KEYES, D.R. REYNOLDS, C.S. WOODWARD, Implicit solvers for large-scale nonlinear problems. Journal of Computational Physics, 2709–2722, 2006.

[2] B. COCKBURN, C.-W. SHU, The local discontinuous Galerkin method for time-dependent convection–diffusion systems. SIAM Journal on Numerical Analysis, 2440–2463, 1998.

[3] J. PERAIRE, P.-O. PERSSON, The compact discontinuous Galerkin (CDG) method for elliptic problems. SIAM Journal on Numerical Analysis, 1806–1824, 2008.