Refined Isogeometric Analysis for Multi-field Problems

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ABSTRACT

Starting from a highly continuous Isogeometric analysis, we introduce hyperplanes that partition the domain into subdomains and reduce the continuity of the discretization spaces along those hyperplanes. As the continuity is reduced, the number of degrees of freedom in the system grows, and the resulting discretization spaces are finer than standard maximal continuity IGA spaces. Despite the increase in the number of degrees of freedom, the time required to solve these finer spaces with direct solvers is faster than with both traditional Finite Element Analysis (FEA) or Isogeometric Analysis (IGA) discretizations when using meshes with a fixed number of elements.

In this work, we analyze the positive impact that continuity reduction along certain hyperplanes has on the number of Floating Point Operations (FLOPs) and computational times required to solve fluid flow and electromagnetic problems with structured meshes and uniform polynomial orders (p). Theoretical estimates show that for sufficiently large grids, an optimal continuity reduction decreases the computational cost of the direct solver by a factor of $O(p^2)$. Numerical results confirm these theoretical estimates. In a 2D mesh with one million elements and polynomial order equal to five, the discretization including an optimal continuity pattern allows to solve a vector electric field, a scalar magnetic field, and a fluid flow problem an order of magnitude faster than when using a highly continuous IGA discretization. 3D numerical results exhibit similar asymptotic savings.

Moreover, the optimal discretizations obtained with rIGA consists of enriched spaces with respect to C^{p-1} IGA. Therefore, the best approximation error is improved by definition.

As future work, we plan to perform a deeper analysis on the effect of the continuity reduction on the total numerical error. In particular, we shall evaluate how significant is the impact of the continuity reduction on the problems' stability.

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