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Efficient isogeometric analysis of lattice structures

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ABSTRACT

Additive Manufacturing (AM) and especially its metal variants constitute today a reality for the fabrication of high-performance industrial components. In particular, AM allows the construction of novel cellular structures, the so-called *lattices*, where well-designed unit cells are periodically repeated over a macro-shape to achieve exceptional specific performances, such as unprecedented stiffness-to-weight ratios. These structures, however, are very difficult to simulate numerically: on the one hand, the application of multiscale methods based on homogenization appears delicate due to an insufficient separation of scales (macro versus cell scales); on the other hand, solving directly the high-fidelity, fine-scale problem requires handling large numbers of complex cells which is often intractable if standard methods are blindly used. As a solution, immersed domain techniques have been applied [1], but such methods, generic in terms of applications, may not be optimal in the case of lattices.

In this context, the purpose of this work is to develop a HPC algorithm dedicated to lattices that takes advantage of the geometric proximity of the different cells in the numerical solution. In order to do so, we start by adopting the CAD paradigm based on spline composition along with its corresponding IGA framework [2]. This offers (i) great flexibility to design any lattice geometry and (ii) fast multiscale assembly of the IGA system by means of look-up tables associated to the cell patterns and macro-fields encoding the behavior of the macro-shape. Then, we resort to the family of Domain Decomposition solvers, and develop an inexact FETI based algorithm [3] that avoids solving numerous local cell-wise systems. More precisely, we extract the “principal” local cell stiffnesses using a greedy approach carried out on the macro-fields, and use the latter as a reduced basis to efficiently solve all the cell-wise systems. It results in a scalable algorithm that tends to be matrix-free. During the talk, a range of numerical examples in 2D and 3D will be presented to account for the efficiency of our method both in terms of memory and computational cost reduction.

REFERENCES

- [1] N. Korshunova, G. Alaimo, S.B. Hosseini, M. Carraturo, A. Reali, J. Niiranen, F. Auricchio, E. Rank, S. Kollmannsberger. Bending behavior of octet-truss lattice structures: Modelling options, numerical characterization and experimental validation. *Materials & Design*, 205, 109693, 2021.
- [2] T. Hirschler, P. Antolin, A. Buffa. Fast and multiscale formation of isogeometric matrices of microstructured geometric models. *Computational Mechanics*, 69, 439-466, 2022.
- [3] M. Bosy, M. Montardini, G. Sangalli, and M. Tani. A domain decomposition method for Isogeometric multi-patch problems with inexact local solvers. *Computers & Mathematics with Applications*, 80, 2604–2621, 2020.