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DNS and LES on unstructured grids: playing with matrices to preserve symmetries using a minimal set of algebraic kernels

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In the last decades, CFD has become a standard design tool in many fields such as automotive, aeronautical and wind power industries. The driven force behind this is the development of numerical techniques in conjunction with the progress of high performance computing (HPC) systems. However, nowadays we can say that its legacy from the 90-2000s is hindering its progress. The reasons are two-fold: (i) codes designed for CPUs cannot be easily ported and optimized to new architectures (GPUs, ARM...) and (ii) legacy numerical methods chosen to solve (quasi)steady problems using RANS models are not appropriate for more accurate (and more expensive) techniques such as LES or DNS. This work aims to interlace these two pillars with the final goal to enable LES/DNS of industrial applications to be efficiently carried out on modern HPC systems while keeping codes easy to port and maintain. In this regard, a fully-conservative discretization for collocated unstructured grids was proposed [1]. It exactly preserves the symmetries of the underlying differential operators and is based on only five discrete operators (*i.e.* matrices): the cell-centered and staggered control volumes (diagonal matrices), Ω_c and Ω_s, the face normal vectors, N_s, the cell-to-face interpolation, $\Pi_{c\rightarrow s}$ and the cell-to-face divergence operator, M. Therefore, it constitutes a robust approach that can be easily implemented in already existing codes such as OpenFOAM® [2]. Then, for the sake of cross-platform portability and optimization, CFD algorithms must rely on a very reduced set of (algebraic) kernels (*e.g.* sparse-matrix vector product, SpMV; dot product; linear combination of vectors). This imposes restrictions and challenges that need to be addressed such as the inherent low arithmetic intensity of the SpMV, the reformulation of flux limiters [3] or the efficient computation of eigenbounds to determine the time-step, Δt. Results showing the benefits of symmetry-preserving discretizations will be presented together with novel methods aiming to keep a good balance between code portability and performance.

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