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HYBRID MPI/OPENMP PARALLEL STRATEGIES FOR A HIGH ORDER DISCONTINUOUS GALERKIN SOLVER IN AERODYNAMICS

E. Martin[1,*] and F. Renac[2]

[1] ONERA, The French Aerospace Lab, BP72 - 29 avenue de la Division Leclerc, FR-92322 CHATILLON CEDEX, `emeric.martin@onera.fr`, `http://www.onera.fr`

[2] ONERA, The French Aerospace Lab, BP72 - 29 avenue de la Division Leclerc, FR-92322 CHATILLON CEDEX, `florent.renac@onera.fr`, `http://www.onera.fr`

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The industrial demand for CFD predictions at an ever-increasing level of detail is the driving force for the development of highly accurate simulation techniques able to predict not only overall features, but also local values of the quantities of interest. At ONERA, the code Aghora is developed for the solution of complex flow systems in aerodynamics, including turbulent flows (RANS, LES, DNS). The main goal is to investigate the potential of high-order schemes based on Discontinuous Galerkin methods (DG) [1, 2] to deliver accurate solutions in this context. The downside of these methods is that they require long execution times and large memory consumptions. Designing efficient algorithms for modern multi-core architectures and developing highly-scalable parallel strategies turn out to be essential to tackle such challenges.

Domain decomposition methods based on a MPI strategy are usually applied to lower the CPU time and memory requirements of these methods. However, this approach may suffer from limitations due to the large number of degrees of freedom per element. In contrast, an OpenMP strategy will allow to offer a second level of partitioning within elements or per groups of elements or edges, and the association of both strategies is under the scope of the present work. We will present three parallel strategies that have been successfully implemented into Aghora. The first one corresponds to a simple MPI approach based on a domain decomposition method with non-blocking and synchronous communications. The second one is based on a hybrid MPI/OpenMP [3, 4, 5] approach, where OpenMP threads are forked only one time per MPI process and remain active during the whole iterative time scheme. The last one concerns another hybrid approach, where threads can now send messages thanks to a certain thread support level of the MPI library and take in charge boundary conditions treatment in parallel.

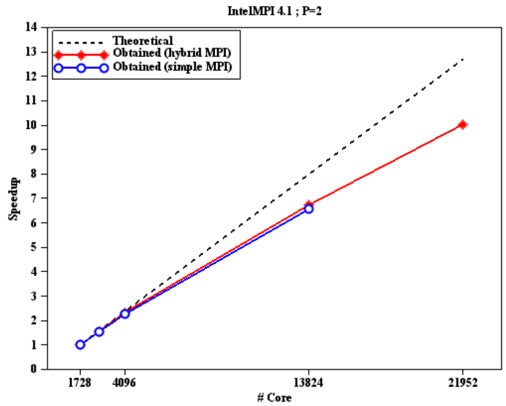

Figure 1: Taylor-Green Vortex DNS - Scalability for $P = 2$

The performances of these approaches will be investigated in the context of real-life applications to compressible turbulent flows with high-order space discretization and explicit and implicit time integration techniques. Numerical experiments will be presented to assess their respective benefits and strong scalability analysis will be showed from several thousands to several tens of thousands computing cores. Sensitivity of the polynomial degree P of the DG method on performance will be discussed, but also the impact of the MPI thread support level choice or the implementation issues arising from the hybrid MPI/OpenMP paradigm. All of these experiments will be done on the Curie supercomputer on nodes composed of two eight-core Intel processors Sandy Bridge in the context of PRACE [6] projects.

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