A CPU-GPU Paradigm to Accelerate Turbulent Combustion and Reactive-Flow CFD Simulations

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The correct solution of ordinary differential equations (ODEs) is particularly relevant for computational fluid dynamic (CFD) simulations involving Lagrangian Particle Tracking, aeroelastic deformation of solids, or combustion. Two critical aspects are encountered in the solution of chemically reactive flow problems: the number of ODE systems to solve, their dimension and stiffness. The solution of the ODE systems has a severe impact on the simulation time and forces the use of parallel, multi-core domain decomposition to fasten the simulations. However, this implies important expenses for the adoption of leadership class machines and the use of several central processing units (CPUs) to reach an adequate acceleration; additionally, the integration seriality for chemical species treatment is not overcome. Graphical Processing Units (GPUs) possess an intrinsic architecture that promotes multiple levels of parallelization. Despite requiring a code reformulation and a CPU/GPU connection, an explicit GPU ODE solver can concurrently handle and solve for multiple cells and species. We present an extension of OpenFOAM capable of adaptive multi-block explicit integration of ODEs systems for the detailed chemical kinetics solution through extensive GPU acceleration. The multi-block ODE solver is coupled to the multi-core parallel CPU algorithm to solve the Navier-Stokes equations for high-speed compressible reactive flows. Tested on different mechanisms and mesh dimensions, it can provide a significant speedup if compared to CPU explicit counterparts.

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