The Parallel Quiet Direct Simulation (QDS) method Applied to Unstructured Tetrahedral Grid Computation using the Intel Phi Coprocessor

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The Quiet Direct Simulation (QDS) method, originally named the Quiet Direct Simulation Monte Carlo (QDSMC), is a Kinetic-theory based approach for Finite Volume Method (FVM) computation of the Euler Equations. The QDS method is based on approximating the flux integrals for flows of conserved quantities between adjacent cells using Gauss-Hermite quadrature. As such, the QDS method is a type of discrete ordinate technique and similar to many existing kinetic-theory-based solvers. The original QDSMC approach required a strictly structured computational grid for the interpolation of mass fluxes from each discrete point to another. The reformation of QDSMC as a conventional Finite Volume Method – hence producing the QDS scheme – allows the computation of fluxes across cell surfaces. This formulation has been previously applied to axisymmetric flows. It follows that the formation should also allow QDS computations using unstructured grids of arbitrary shape and structure. Here, we apply the QDS scheme to unstructured finite volume computation using tetrahedral meshes. Due to the surface flux formulation employed, the solver is a direction decoupled method, unlike earlier QDSMC and QDS solvers. Due to the fact that the QDS approach is fundamentally a transient flow solver, we limit the large computational expense through the use of OpenMP parallelization using the Intel Phi Coprocessor. During the presentation, we will compare the performance of unstructured QDS using the Phi device against conventional parallelization using standard Intel Xeon cores. The presentation shall outline the importance of vectorization for parallel performance – both on conventional CPU's and the Phi coprocessor – and show several other results associated with the use of a discrete ordinate solver on an unstructured computational grid.