Title: Evaluating the Maturity of OpenFOAM Simulations on GPGPU for Bio-fluid Applications

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Abstract.

We investigated the challenges facing CFD solvers as applied to bio-medical fluid flow simulations and in particular the OpenFOAM 2.1.1 solver, icoFoam, for the large penta-diagonal matrices coming from the simulation of blood flow in arteries with a structured mesh domain in PRACE-3IP project at TGCC Curie (a modern Tier-0 system) (see [1] and references therein). We generated a structured mesh by using blockMesh as a mesh generator tool. To decompose the generated mesh, we employed the decomposePar tool. After the decomposition, we used icoFoam as a flow simulator/solver tool. We achieved scaled speed-up for large matrices up to 64 million x 64 million matrices and speed-up up to 16384 cores on Curie.

Recently, we tested OpenFOAM "icoFoam" simulator with various iterative solvers such as diagonal incomplete LU preconditioned bi-conjugate gradient, generalised geometric algebraic multi-grid and incomplete cholesky preconditioned conjugate gradient, in addition to direct solvers such as distributed SuperLU (see [2]). Also, we tested several flow simulators such as nonNewtonianIcoFoam. nonNewtonianIcoFoam is used to simulate non-newtonian flows while pisoFoam is for incompressible turbulent flow. We used snappyHexMesh tool to construct unstructured mesh in arbitrary shapes such as real artery geometries, as needed. We compared the performance, scalability and robustness of OpenFOAM on GPGPU. We will present our results regarding the speed-up of direct solver for 16 million and 20 million meshes on Curie hybrid nodes using MPI+OpenMP+GPU. The authors thank to PRACE, GENCI and CEA for the opportunity to conduct our research in the frame of the Project 2010PA2505 awarded under the 18th Call for PRACE Preparatory Access.

[1] A. Duran, M.S. Celebi, S. Piskin, and M. Tuncel, Scalability of OpenFOAM for Bio-medical Flow Simulations, Journal of Supercomputing, 71(3), 2015, pp. 938-951, DOI 10.1007/s11227-014-1344-1 Springer Link. This work was financially supported by the PRACE Project funded in part by the EUs 7th Framework Programme (FP7/2007–2014) under Grant agreement No. RI-312763, (see PRACE white paper WP 162 for an early version, June 9, 2014)

[2] X. S. Li, J. W. Demmel, J. R. Gilbert, L. Grigori, M. Shao, and I. Yamazaki, SuperLU Users' Guide, Tech. Report UCB, Computer Science Division, University of California, Berkeley, CA, 1999, update: 2011