Bidirectional coupling of acoustics and flow on massively parallel systems

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Acoustic problems, where the sound-waves interact with their generating source are typical multi-scale applications. These kinds of problems are hard to tackle numerically due to the physical effects on different scales, that need to be considered. For noise generation the fact can be exploited that the noise generating scale usually is spatially confined and the interaction with sound wave propagation can be realized at the surface of this confinement. We exploit this fact in the method for direct aero-acoustic simulations in this work by using a coupled approach of spatially separated domains. Each domain is discretized with the most suitable numerical method, and the coupling is realized with a generic coupling tool, that takes care of the necessary interpolation between the different discretizations.

Aero-acoustic propagation is a linear wave phenomenon and can be excellently solved by high order methods. Besides their fast error convergence for smooth solutions, high order methods also provide little dissipation and dispersion, which is important for the correct representation of waves. To achieve the high order representation on parallel systems, we apply Discontinuous Galerkin methods, which can be distributed by partitioning the mesh of the domains. A high order representation has the additional advantage of little communication between elements in the Discontinuous Galerkin context. Inherited from this, partitions on distributed processes have to exchange only small amounts of data, resulting in a high parallel efficiency. The solvers are part of the parallel simulation framework APES [1] that includes pre- and post-processing and enables the computation of large scale engineering problems with complex geometries on distributed and parallel high performance computing systems. It has been shown, that for this method a parallel efficiency of 88% on up to 131,072 cores of the large scale computing system SuperMUC at LRZ, Munich can be maintained.

Also for the flow simulation which is dominated by non-linear effects, we concentrate in this contribution on a high order Discontinuous Galerkin discretization of this domain as well. We demonstrate how the generic coupling library *preCICE* [2] can be used to couple a linear with a non-linear high order domain where different resolutions are applied in the corresponding parts of the computational domain. The coupling approach allows for a restriction of the computational effort, that needs to be spent on solving the non-linear noise generation, to the small domain, where it is actually required, while the large domain of wave propagation can be solved with the linear acoustic equations. Numerical experiments of this setup are shown, and a large scale direct aero-acoustic simulation of noise in a closed room is presented.

References

[1] S. Roller, J. Bernsdorf, H. Klimach, M. Hasert, D. Harlacher, M. Cakircali, S. Zimny, K. Masilamani, L. Didinger, and J. Zudrop. *An adaptable simulation framework based on a linearized octree*. In M. Resch, X. Wang, W. Bez, E. Focht, H. Kobayashi, and S. Roller, editors, High Performance Computing on Vector Systems 2011, pages 93105. Springer Berlin Heidelberg, 2012.

[2] H.-J. Bungartz, J. Benk, B. Gatzhammer, M. Mehl and T. Neckel, *Partitioned Simulation of Fluid-Structure Interaction on Cartesian Grids*. In H.-J.Bungartz, M. Mehl and M.Schäfer,editors,Fluid-Structure Interaction – Modelling, Simulation, Optimisation, Part II,pages 255-284,Springer Berlin,Heidelberg, 2010.