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COUPLING OF TURBULENT FLOWS WITH ACOUSTIC WAVE PROPAGATION

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This work is concerned with the direct aero-acoustic wave simulation of noise produced by turbulent flows as found close to structures. Fluid Acoustic Interaction yield a multi-scale problem including different lengthscales where solving large problems with a monolithic approch would be too expensive. However, the different phenomena typically appear in spatially separated domains. Thus, it is possible to decompose the overall simulation domain into non-overlapping parts with distinctive treatment. By separating the scales of the problem this way, numerical treatment of large and complex problems becomes feasible as adapted methods and resolutions can be used in the individual subdomains. Typically, there is a domain around the complex geometry where the flow is turbulent and sound is generated. For this regime, fine meshes are needed and the full set of non-linear equations has to be solved. Further away from the geometry, only propagation of the acoustic waves is relevant. Here, the mesh can be much coarser, and the set of equations can be reduced to the linearized Euler equations. Our focus in this work is the usage of high order schemes with low dissipation for the acoustic linear wave propagation and its surface coupling with a non-linear flow solver used to simulate the noise generation. These direct simulations deepen the understanding of noise generation and propagation and help to produce better designs with reduced noise.

Our approach is based on a heterogeneous domain decomposition, where the individual domains are coupled with each other via boundary conditions. Considering compressible flows, we deploy explicit time stepping schemes, which allows for a straight forward data exchange at the interfaces. Applying a proper data exchange at the boundaries allows for the deployment of different schemes, equations and methods in each regime. Hence, the numerical approximation can be fine-tuned to the individual requirements in each regime. Especially for the far field, where only wave propagation has to be considered, high order methods with low dissipation are attractive. In this work we concentrate on a high order modal Discontinuous Galerkin method for this regime and how it can be coupled to the near field. As there are usually no, or only few, obstacles in the far field, the elements of the mesh can be sufficiently large to justify high order approximations with polynomial degrees in the range of 100. Due to the exponential convergence for spectral schemes, this enables the efficient solution of large problems. In the scope of this work, we investigate the feasibility of such high order discretizations in combination with a coupling method for neighboring domains.

Even though, the decomposition approach greatly reduces the costs for the overall simulation, the settings we are aiming for are still demanding in terms of computational power. Therefore, our implementation in the *APES* framework [1] is designed to take advantage of the massively parallel systems available in supercomputing today. The framework relies on a distributed octree mesh representation that, due to its known topology, minimizes the required global information for neighborhood identifications. Arbitrary geometries can be covered by the octree mesh and it is perfectly suitable for the deployed Discontinuous Galerkin method. The polynomial degree, used in the approximation of the solution for the linear wave propagation, is basically only limited by the memory available to each node in the distributed computing system. It can therefore be chosen accordingly to fit the machine as good as possible.

Interpolation, datamapping and steering between the domains is achieved by deploying the coupling tool *PreCICE* [2]. Using this tool, different solvers can easily be coupled and a high independence of the individual domains is maintained. We describe the setup for the parallel and coupled simulation on HPC systems in detail and explore the feasibility of this approach in direct aero-acoustic simulations. Furthermore, we investigate parameters such as dicretization, synchronization timestep and interpolation method regarding accuracy, stability, as well as speed of execution.

The analysis is done with a subsonic but compressible flow around an obstacle. This results in a vortex street and is a typical scenario for many technical devices generating noise.

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