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APPLICATION OF AN EXPLICIT DISCONTINUOUS GALERKIN SCHEME TO TURBULENT FLOWS AT INTERMEDIATE TO HIGH REYNOLDS NUMBERS

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In recent years substantial progress has been made in CFD in the field of high order methods in general and specifically discontinuous Galerkin methods. While still being a topic of active research they exhibit large potential for industrial applications. For industrial use especially the simulation of well resolved turbulent flows is of vital importance. While stationary problems can be handled very well by state-of-the-art finite volume methods, there is still a need for improvement with respect to unsteady flows. To appropriatly cover the physics of unsteady flows, the main requirement is high resolution both in space and time. It was shown that high order discontinuous Galerkin methods posses great strenghts in this field [1], due to their good scale resolving capabilities.

In this work we apply an explicit discontinuous Galerkin spectral element method (DGSEM) [2] to two well investigated and demanding problems for medium to very high Reynolds number flows. The first testcase is an incompressible channel flow over a periodic hill-shaped geometry at a Reynolds number of 10,985, based on the hill height. The periodic hill flow represents a classical problem for LES computations and is frequently used in the field of turbulence modelling. As it features a variety of different flow phenomena, namely separation, turbulent transition and reattachment followed by a recovery region, it is very sensitive to both numerics and turbulence modelling. In recent times Breuer et al. [3] have performed LES and DNS computations for this case at many different Reynolds numbers, serving as references results for the ERCOFTAC database.
For our high order computations we rely on numerical dissipation and utilize an overintegration strategy for dealiasing. On a single coarse mesh we employ polynomial degrees from N=3 to N=9, where the number of degrees of freedom for the highest polynomial degree is still well below that of the reference computations. We show that with less degrees of freedoms our results are on par with the reference results.

The second case which was investigated is a fully compressible flow over the M219 cavity

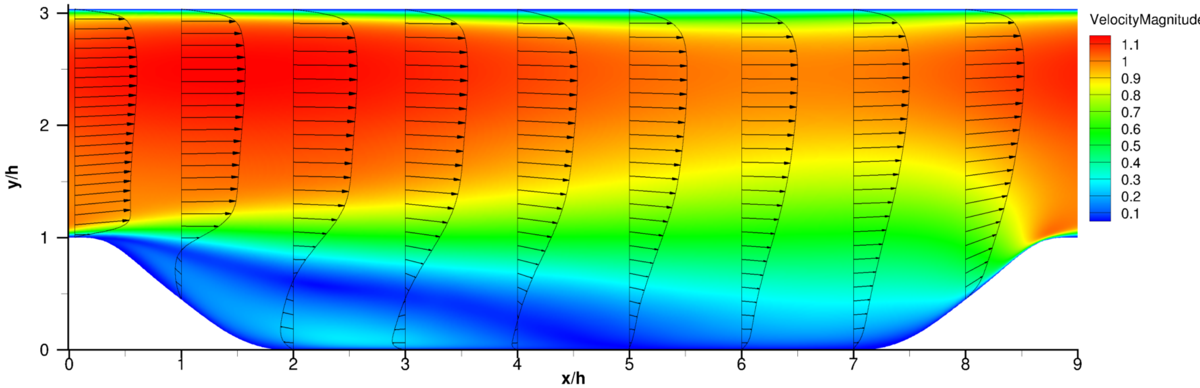

Figure 1: Velocity magnitude and velocity direction for the periodic hill testcase

at Ma=0.85 and a Reynolds number of 6.8 million based on the cavity length. Extensive numerical studies of this testcase can be found in the work of Larchevêque et al. [4], including a detailed description. Due to the high Reynolds number, no DNS results exist for this case, we will therefore compare against experimental results and other LES results. Above the cavity a shear layer develops, featuring a Kelvin-Helmholtz instability, and thickens up downstreams. On the cavity floor self-sustaining pressure fluctuations (Rossiter modes) can be observed.

At the example of the periodic hill, we investigate the behaviour of the method for well-resolved to slightly underresolved LES scenarios at medium Reynolds numbers, where the method is expected to have its natural strenghts compared to second order schemes. The high Reynolds case is by design vastly underresolved, and still requires a massive amount of computing time. Here we demonstrate that our DGSEM framework can efficiently handle problems of this magnitude by taking advantage of the inherent parralelization capabilities of the scheme. Furthermore we show that the benefits due to higher accuracy carry over to these underresolved scenarios.

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