Isogeometric Analysis for Compressible Flows. Design Principles and Code Development of a Flow Solver for Heterogeneous Systems

Matthias Möller* and Andrzej Jaeschke†

* Delft Institute of Applied Mathematics (DIAM)
Delft University of Technology
Van Mourik Broekmanweg 6, 2628 XE Delft, The Netherlands
e-mail: m.moller@tudelft.nl,

† Institute of Turbomachinery
Lodz University of Technology
Wolczanska 219/223, 90-924 Lodz, Poland
Email: andrzej.jaeschke@p.lodz.pl

ABSTRACT

In this talk, we present recent developments of our compressible flow solver that is implemented in the open-source Isogeometric Analysis library G+Smo (Geometry plus Simulation Modules) [1].

The flow solver is based on a generalization of the Algebraic Flux Correction (AFC) paradigm [2] to higher-order B-Spline functions and adopts strong stability preserving explicit Runge-Kutta time-integration schemes for advancing the solution forward in time [3]. It is shown during the talk that the AFC approach is able to reliably suppress the generation of spurious oscillations in the vicinity of shocks and steep solution gradients also for high-order approximations. The coupling between patches is realized via a discontinous Galerkin formulation to reduce communication overhead.

The main part of the talk addresses the software design principles of the developed code which follow a hardware-oriented co-design approach, that is, both the geometry model and the solution algorithm are designed in such a way that they can be easily run on heterogeneous compute systems. In particular, the core of the flow solver makes use of the open-source Fluid Dynamics Expression Template library FDBB [4] which allows us to implement the mathematical algorithm as a generic single-patch compute kernel in high-level hardware-independent C++ code that gets just-in-time compiled and thereby hardware-optimized for each individual patch at run time. This makes it possible to combine CPUs with GPUs and other accelerator devices. This flexibility is achieved by resorting to highly efficient, hardware-optimized linear algebra backends like ArrayFire, Blaze, Eigen, and VexCL which can be mixed between patches. The discontinuous Galerkin-type coupling of patches simplifies the data exchange, especially between patches with different compute backends.

Numerical examples for several flow problems will be shown including performance benchmarks.

REFERENCES

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