Technische Universität Braunschweig

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Robust and efficient high-performance computational fluid dynamics enabled by modern numerical methods and technologies

Lecture of

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Computational fluid dynamics is an active and fruitful area of research. From an engineering point of view, the currently available tools based on the compressible Euler and Navier-Stokes equations are routinely used, for example to design airplanes or high-speed Formula 1 cars. From a mathematical point of view, compressible fluid dynamics provides a rich set of challenges --- there is no satisfying well-posedness theory of these nonlinear equations in the presence of discontinuities and/or turbulence in multiple space dimensions. Nevertheless, both perspectives are connected by the common thread of structure-preserving discretizations, in particular entropy-based methods. On the one hand, satisfying a version of the second law of thermodynamics discretely has been shown to improve the robustness of numerical methods. On the other hand, such entropy estimates and related positivity constraints form the basis of evolving convergence and existence theories. In this talk, we review these recent developments and present Trixi.jl, an open source Julia package implementing entropy-based high-order methods efficiently in a discontinuous Galerkin framework. We review some aspects of computational efficiency and robustness, including a discussion of the common approach to control the time step size based on a Courant-Friedrichs-Levy (CFL) estimate and the alternative using error-based step size controllers. Finally, we comment on our use of Julia, a modern programming language developed at MIT.