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NEXT GENERATION OF COMPRESSIBLE CFD SOLVERS: WHY? WHAT? WHEN? HOW?

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Abstract. Next-generation numerical algorithms for accurately solving advanced flow problems with complex geometries will undoubtedly rely on robust and efficient high-order accurate formulations for unstructured grids. Adaptive high order schemes have the potential to drastically improve the computational efficiency required to achieve the desired error level, but almost all of them are less robust than their low order counterparts when the numerical solution contains discontinuities or even under-resolved physical features (e.g., under-resolved turbulent flows). Although there is much work to be done to develop the theory behind the stability, consistency, and accuracy of algorithms as we increase asynchrony, reduce communication, and decompose problems in search of more concurrency, we do not want expensive and time-consuming simulations to fail because the underlying spatial and temporal discretizations are unstable. Therefore, because the scale of many numerical models and physical problems targeted computational science exacerbates the stability difficulties (the exascale era is also not too far), the use of fully controllable non-linearly stable complex simulation algorithms is necessary. While incremental improvements to existing and widely used algorithms will continue to improve overall capabilities, the development of new numerical techniques and their extension to complex multi-scale and multi-physics problems offers the possibility of radically advanced computational fluid dynamics and beyond. We are currently at a critical development stage with high order methods, where we can mimic important continuous stability estimates in time and space by carefully constructing discrete operators. However, the advancement of numerical schemes and their properties go hand-to-hand with analytical knowledge about the physical models. It is almost impossible to progress with the numerical algorithms further than we analytically know: Thus, which properties are important? Or, more fundamentally, how do we prove the convergence of the numerical solution to a physical solution for a given PDE model? We can only answer this question if researchers from several disciplines, including physics, mathematics, and computer science, collaborate altogether.

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