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An asynchronous discontinuous Galerkin method for combustion simulations

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The discontinuous Galerkin (DG) method has emerged as a promising approach for developing scalable flow solvers, owing to its high arithmetic intensity and superior capability in resolving discontinuities such as shocks and detonations. However, its scalability is degraded by communication bottlenecks arising from data exchange and its synchronization at large processor counts. To address these communication overheads, an asynchronous computing framework based on finite-difference schemes was previously introduced, offering arbitrary-order accuracy, and their scalability was demonstrated for simple partial differential equations (PDEs) [1, 2]. Building on this foundation, the asynchronous discontinuous Galerkin (ADG) method was recently developed to reduce communication overheads by relaxing synchronization or by periodically avoiding communication [3]. While earlier studies verified the numerical properties of the ADG method using simple one-dimensional PDEs, the current work extends its applicability to complex chemically reacting flows relevant to combustion applications. Specifically, we investigate the ability of the ADG method to capture flame fronts and detonation waves with high fidelity. To this end, new asynchrony-tolerant weighted essentially non-oscillatory (AT-WENO) limiters are formulated to accurately resolve discontinuities in the presence of communication delays at processor boundaries. To demonstrate the accuracy of the ADG method, the simple problem of a premixed spontaneous ignition with detailed chemical kinetics is first considered. Results show that the flame front is captured with high accuracy, and errors induced at processor interfaces remain negligible. The efficacy of the AT-WENO limiters is then demonstrated through the simulation of a propagating detonation wave. These findings establish the ADG framework as a promising direction for the development of highly scalable DG-based solvers for reacting flow simulations on next-generation supercomputing platforms.

References

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