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Accurate Simulation of Multi-Dimensional Detonation Waves in a Shock-Attached Frame

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Numerical simulation of detonation waves is a challenging problem due to resolution requirements necessary to compute highly nonlinear multiple-scale dynamics of the shock–reaction zone structure. Widely used shock-capturing techniques are often inadequate when dealing with unstable detonations. Large errors at the lead shock propagate into the reaction zone, amplify, and can dominate the true dynamics of the detonation instability. In order to eliminate the shock-capturing errors at the lead shock, we propose a shock fitting algorithm that is based on numerical integration of the reactive Euler equations in the frame attached to the lead shock. A local system of hyperbolic partial differential equations on the shock coupled to the Euler equations inside the reaction zone is derived and used as part of a numerical algorithm. With high-order time- and space discretizations, we compute the growth of linear instability into non-linear cellular detonation waves. For the first time, we performed detailed verification of the results of detonation stability theory in two dimensions. Our approach is ideally suited for testing detonation stability theories as well as nonlinear asymptotic theories such as detonation shock dynamics.