P54 A Modern Blast Solver Strategy and its Urban Applications

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Abstract:

The nature of simulating blast effects from explosives and in real urban environments requires a CFD-based approach solved on highly discretized 3D domains. First-principles hydrocodes and CFD codes have traditionally been adapted for high-performance computing in distributed environments. The current trend in modern hardware involves many-core architectures, such as multi-processor multi-core CPU and multiple graphics processing units (GPU), often configured together on individual compute nodes. Thus, a next-generation CFD blast code has been developed to employ hybrid GPU/ CPU shared-memory computing, which makes optimal use of heterogeneous compute cores in either a workstation or server, and is also scalable to modern parallel clusters. The goal of this modern blast solver is a 50 times speedup using GPU acceleration as compared with its predecessor – e.g., the Chinook code – running on one core of a standard CPU. This up-to-date development necessitated novel solution strategies, including: hybrid shared/distributed memory structure, CFD code optimization for many-core general-purpose GPU, and concurrent CPU/GPU task parallelization. A compact storage technique based on Cartesian meshes combines a zonal meshing strategy, patch-based adaptive mesh refinement (AMR), and dynamic Eulerian remapping to ensure maximum resolution of blast effects. The fundamental solver calculation time is 4 – 10 times faster than Chinook's unstructured mesh CFD solver, and the GPU computing using a scientific NVIDIA card is 10 – 30 times faster than a single CPU core, resulting in a potential combined total close to two orders-of-magnitude speedup. Further speedup is achieved using the patch AMR as compared with uniform meshes. In this paper, the combined speedup and optimal use of features and computing capability is assessed for practical urban situations. This modernized CFD blast solver has been integrated into a tool called the Rapid City Planner for prediction of urban explosion events using real city geometry. Building structures and urban terrain are automatically meshed and are embedded in the new solver using the immersed boundary method (IBM) technique. Validation with benchmark numerical solutions and urban blast experimental data has been conducted. Due to the high level of automation in the Rapid City Planner and the novel use of GPU computing in the new solver, uncertainty quantification is required in addition to accuracy assessment. The sensitivity of the urban blast results to mesh orientation, explosive placement, and environment geometry are evaluated using perturbation methods, while uncertainties in real city geometry are discussed. More rigorous uncertainty quantification in the field of CFD is particularly challenging for shock wave applications, and is left for future work in connection with the GPU numerical solutions.

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