SPH-EXA: Enhancing the Scalability of SPH codes Via an Exascale-Ready SPH Mini-App

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Numerical simulations of fluids in astrophysics and computational fluid dynamics (CFD) are among the most computationally-demanding calculations, in terms of sustained floating-point operations per second, or FLOP/s. It is expected that these numerical simulations will significantly benefit from the future Exascale computing infrastructures, that will perform 10ˆ18 FLOP/s. The performance of the SPH codes is, in general, adversely impacted by several factors, such as multiple time-stepping, long-range interactions, and/or boundary conditions. In this work an extensive study of three SPH implementations SPHYNX, ChaNGa, and XXX is performed, to gain insights and to expose any limitations and characteristics of the codes. These codes are the starting point of an interdisciplinary co-design project, SPH-EXA, for the development of an Exascale-ready SPH mini-app. We implemented a rotating square patch as a joint test simulation for the three SPH codes and analyzed their performance on a modern HPC system, Piz Daint. The performance profiling and scalability analysis conducted on the three parent codes allowed to expose their performance issues, such as load imbalance, both in MPI and OpenMP. Two-level load balancing has been successfully applied to SPHYNX to overcome its load imbalance. The performance analysis shapes and drives the design of the SPH-EXA mini-app towards the use of efficient parallelization methods, fault-tolerance mechanisms, and load balancing approaches.