Towards a Mini-App for Smoothed Particle Hydrodynamics at Exascale

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The smoothed particle hydrodynamics (SPH) technique is a purely Lagrangian method, used in numerical simulations of fluids in astrophysics and computational fluid dynamics, among many other fields. SPH simulations with detailed physics represent computationally-demanding calculations. The parallelization of SPH codes is not trivial due to the absence of a structured grid. Additionally, the performance of the SPH codes can be, in general, adversely impacted by several factors, such as multiple time-stepping, long-range interactions, and/or boundary conditions. This work presents insights into the current performance and functionalities of three SPH codes: SPHYNX, ChaNGa, and SPH-flow. These codes are the starting point of an interdisciplinary co-design project, SPH-EXA, for the development of an Exascale-ready SPH mini-app. To gain such insights, a rotating square patch test was implemented as a common test simulation for the three SPH codes and analyzed on two modern HPC systems. Furthermore, to stress the differences with the codes stemming from the astrophysics community (SPHYNX and ChaNGa), an additional test case, the Evrard collapse, has also been carried out. This work extrapolates the common basic SPH features in the three codes for the purpose of consolidating them into a pure-SPH, Exascale-ready, optimized, mini-app. Moreover, the outcome of this serves as direct feedback to the parent codes, to improve their performance and overall scalability.
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