Universität Basel

Research Project

SPH-EXA: Optimizing Smooth Particle Hydrodynamics for Exascale Computing

Third-party funded project

Project title SPH-EXA: Optimizing Smooth Particle Hydrodynamics for Exascale Computing
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Understanding how fluids and plasmas behave under complex physical conditions is on the basis of some of the most important questions that researchers try to answer. These range from practical solutions to engineering problems to cosmic structure formation and evolution. In that respect, 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 (FLOP/s). It is expected that they will benefit greatly from the future Exascale computing infrastructures, that will perform 1018 FLOP/s. This type of scenarios pushes the computational astrophysics and CFD fields well into sustained Exascale computing. Nowadays, they can only be tackled by either reducing the scale, the resolution and/or the dimensionality of the problem, or using approximated versions of the physics involved. How this affects the outcome of the simulations, and therefore our knowledge on the problem, is still not well understood.

The simulation codes used in numerical astrophysics and CFD (hydrocodes, hereafter) are numerous and varied. Most of them rely on a hydrodynamics solver that calculates the evolution of the system to be studied along with all the coupled physics. Among these hydrodynamics solvers, the Smooth Particle Hydrodynamics (SPH) technique is a purely Lagrangian method, with no subjacent mesh, where the fluid can freely move in a practically boundless domain, this being very convenient for astrophysics and CFD simulations. SPH codes are very important in astrophysics because they couple naturally with the fastest and most efficient gravity solvers such as tree-code and fast multiple methods. Nevertheless, the parallelization of SPH codes is not straightforward due to its boundless nature and the lack of a structured grid, causing continuously changing interactions between fluid elements or between fluid elements and mechanical structures, from one time-step to the next. This, indeed, poses an additional layer of complexity in parallelizing SPH codes, yet it also renders them a very attractive and challenging application for the computer science community in view of its parallelization and scalability challenges for the upcoming Exascale computing systems.

We aim in this project to have a scalable and fault tolerant SPH kernel, developed into a mini/proxy co-design application. The SPH mini-app will be incorporated into current production codes in the fields of astrophysics (SPHYNX, ChaNGa), and CFD (SPH-flow), producing what we call the SPH-EXA version of those codes.

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ID	Kreditinhaber	Kooperationspartner	Institution	Laufzeit - von	Laufzeit - bis
3403514	Ciorba, Florina M.	Banicescu, Ioana, Professor and Director of NSF Center for Cloud and Autonomic Computing	Mississippi State University	01.12.2008	31.12.2043
4256117	Ciorba, Florina M.	Quinn, Tom, Professor	Department of Astronomy University of Washington in Seattle	01.09.2017	30.06.2020
4256146	Ciorba, Florina M.	García-Senz, Domingo, Professor	Department of Physics and Nuclear Engineering (FEN), Universitat Politècnica de Catalunya	01.09.2017	30.06.2020
4266021	Ciorba, Florina M.	Mayer, Lucio, Professor	University of Zurich	01.09.2016	31.12.2043