In-Situ Visualization and Analysis for SPH Simulations

Jean M. Favre
CSCS/ETHZ
Switzerland
jean.favre@cscs.ch

Jean-Guillaume Piccinali
CSCS/ETHZ
Switzerland
jgp@cscs.ch

Rubén Cabezón
University of Basel
Switzerland
ruben.cabezon@unibas.ch

Many Smoothed Particle Hydrodynamics codes suffer from limited scalability in the writing throughput with increasing number of fluid elements. For example, while DualSPHysics uses the BINX4 binary format as default to save particle properties in output files, scaling tests with increasing numbers of fluid particles show a rapid decline in writing speed, from 12,400 particles/second for 49,599 particles to 3,020 particles/second for 636,172 particles.

Similar slowdowns may occur with alternative formats used in other SPH codes, notable examples include Tipsy (used by Changa and Pkdgrav), Numpy (used by PySPH), VTP (used by SPHinXsys) and HDF5 (used by Gadget, Flash, Swift and SPH-EXA).

To address these limitations, this poster explores the advantages of in-situ data analysis and visualization, successfully applied in SPH-EXA, now under the focus of a different code, DualSPHysics. These methods minimize data transfers, execution time, memory usage, and integration efforts while enabling real-time analysis.

We begin with the VTK-m library which is a lightweight C++ library with a very flexible data model, supporting varied native memory layout (strided data arrays, or sets of individuals data arrays per variable) and device-resident or host-based data access, with a number of filters and I/O modules which can be compiled into any SPH application code.

We follow with the Ascent library, which adds another dependency, the "Conduit" library for describing hierarchical scientific data. Adding meta-data description enables the decoupling of simulation codes and visualization codes, with Conduit data acting as bridges. An application compiled with Ascent becomes a data consumer without the need to recompile the application. Ascent brings the flexibility of defining visualization scripts at run-time. We demonstrate the straightforward integration of Ascent into DualSPHysics and show how its API can dynamically visualize and analyze the results of several test cases included in the full DualSPHysics/v5.2 package.

Finally, we examine ParaView/Catalyst, leveraging its GUI to define visualization pipelines and connect directly to DualSPHysics simulations instrumented with the Conduit data definitions.

Preliminary results including in-situ visualizations on the Swiss National Supercomputing Center's Alps system, with further tests using advanced SPH cases to follow. We aim to provide simulation developers with practical insights and guidelines for enabling efficient and rapid analysis of SPH datasets.

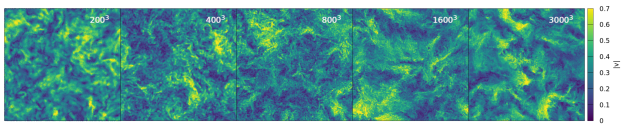

Fig. 1. Slice of the module of the velocity field with increasing resolution and calculated with SPH-EXA.

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