VTK-m: Accelerating the Visualization Toolkit for Multi-core and Many-core Architectures

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VTK-m Goals
- A single place for the visualization community to collaborate, contribute, and leverage massively threaded algorithms
- Reduce the challenges of writing highly concurrent algorithms by using data parallel algorithms
- Make it easier for simulation codes to take advantage these parallel visualization and analysis tasks on a wide range of current and next-generation hardware
- Unify efforts in this area from Sandia (Dax), Oak Ridge (EAVL), and Los Alamos (PISTON)

VTK-m Status
- Project infrastructure
  - Code repository: https://gitlab.kitware.com/vtk/vtk-m
  - Project webpage: http://m.vtk.org
- Features
  - Core Types
  - Statically Typed Arrays
  - Dynamically Typed Arrays
  - Device Interface (Serial, CUDA, TBB; OpenMP in progress)
  - Field and Topology Worklet and Dispatcher
- Data Model
  - Allows clients to construct data sets from cell and point arrangements that exactly match their original data
  - In effect, this allows for hybrid and novel mesh types
- Filters
  - Isosurface for structured grids
  - Statistical filters (histograms, moments, etc.)
  - In development: stream lines, stream surfaces, tetrahedralization

Cosmology Applications
- Halo finding and halo center finding algorithms were written using PISTON, one of VTK-m’s constituent projects
- On Titan, this enabled centers to be found on the GPU ~50x faster than using the pre-existing algorithms on the CPU (with one rank per node)
- This work allowed halo analysis to be completed on all time steps of a very large 8192$^3$ particle data set across 16,384 nodes on Titan for which analysis using the existing CPU algorithms was not feasible
- The portability of VTK-m allowed us to run the same code on an Intel Xeon Phi
- This is the first time that the c-M relation has been measured from a single simulation volume over such an extended mass range

Hardware-Agnostic Ray Tracing
- VTK-m’s hardware-agnostic approach gives comparable performance to hardware-specific approaches
- Since VTK-m is implemented in a hardware-agnostic way, we wanted to understand the corresponding sacrifice in performance
- We implemented a ray-tracer, which is computationally intensive and uses many unstructured memory accesses
- We then compared VTK-m’s performance to NVIDIA’s OptX and Intel’s Embree, two “guaranteed not to exceed” ray-tracing standards that are developed by teams of professionals
- Our study found that VTK-m performance was always within a factor of two of industry standards, and even outperformed them in some cases
- We concluded that VTK-m hardware-agnostic approach is viable - our single implementation performed comparably to multiple hardware-specific implementations

In-situ Applications
- Tightly coupled in-situ with EAVL, one of VTK-m’s constituent projects
  - Efficient in-situ visualization and analysis
    - Light weight, zero-dependency library
    - Zero-copy references to host simulation
    - Heterogeneous memory support for accelerators
    - Flexible data model supports non-physical data types
    - Example: scientific and performance visualization, tightly coupled EAVL with SciDAC Xolotl plasma surface simulation
  - Loosely coupled in-situ with EAVL
    - Application de-coupled from visualization using ADIOS and Data Spaces
    - EAVL plug-in reads data from staging nodes
    - System nodes running EAVL perform visualization operations and rendering
    - Example: field and particle data, EAVL in-situ with XGC
    - VTK-m’s hardware-agnostic approach gives comparable performance to hardware-specific implementations

Advanced Visualization Usability Study
- Implementation of both ray-casting and cell projection volume rendering algorithms using Dax, one of VTK-m’s constituent projects
- Complied for CUDA, OpenMP, and Intel’s Thread Building Blocks
- Comparative performance study on NVIDIA Titan X GPU, Intel Xeon, and Intel Xeon Phi
- VTK-m implementation in progress

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