Production-quality Tools for Adaptive Mesh Refinement Visualization

Gunther H. Weber[1], Hank Childs[2], Kathleen Bonnell[2], Jeremy Meredith[3],
Mark Miller[2], Brad Whitlock[2], E. Wes Bethel[1]
[1]Lawrence Berkeley National Lab.; [2]Lawrence Livermore National Lab.; [3]Oakridge National Lab.

Summary

Adaptive Mesh Refinement (AMR) is a highly effective simulation method for spanning a large range of spatiotemporal scales, such as astrophysical simulations that must accommodate ranges from interstellar to sub-planetary. Most mainstream visualization tools still lack support for AMR as a first class data type and AMR code teams use custom built applications for AMR visualization. The Department of Energy's (DOE's) Science Discovery through Advanced Computing (SciDAC) Visualization and Analytics Center for Enabling Technologies (VACET) is extending and deploying VisIt, an open source visualization tool that accommodates AMR as a first-class data type, for use as production-quality, parallel-capable AMR visual data analysis infrastructure. This effort will help science teams that use AMR-based simulations and who develop their own AMR visual data analysis software to realize cost and labor savings.

Adaptive Mesh Refinement (AMR) techniques combine the compact, implicitly specified structure of regular, rectilinear with the adaptivity to changes in scale of unstructured grids. Handling AMR data for visualization is challenging, since coarser information in regions covered by finer patches is superseded and replaced with information from these finer patches. During visualization, it becomes necessary to manage selection of which resolutions are being used for any given visualization operation. Furthermore, it is difficult to avoid discontinuities at level boundaries, which, if not properly handled, lead to visible artifacts in visualizations. Due to these difficulties, AMR support as first class data type in production visualization tools has been lacking despite the growing popularity and usefulness of AMR simulations.

VisIt is an open source visualization tool that accommodates AMR as first class data type. VisIt handles AMR data as a special case of "ghost data," i.e., data that is used to make computations more efficient, but which is not considered to be

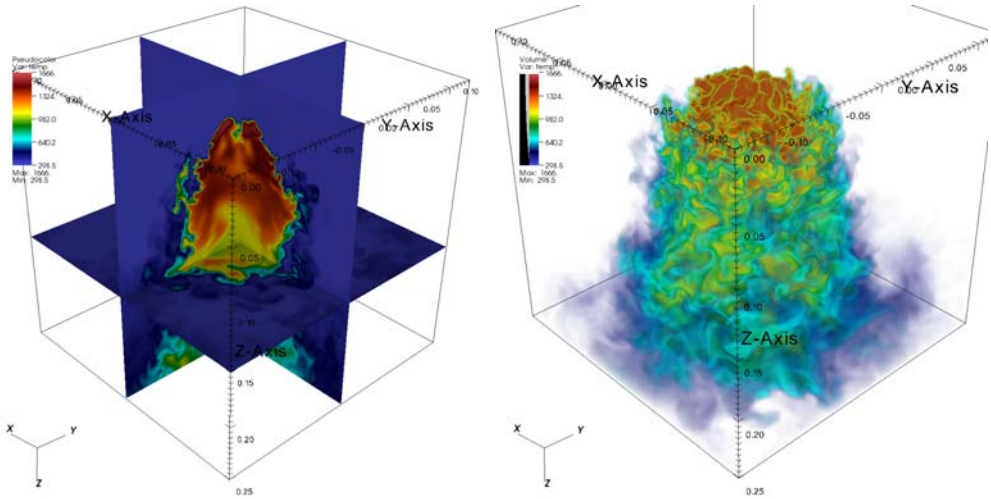

Figure 1: Production-quality visualization of an AMR simulation of a hydrogen flame (Sample data courtesy J. Bell and M. Day, Center for Computational Sciences and Engineering, LBNL). The left panel shows a pseudocolor plot restricted to three axis-perpendicular slices. The right panel shows a volume rendered image of the same data.

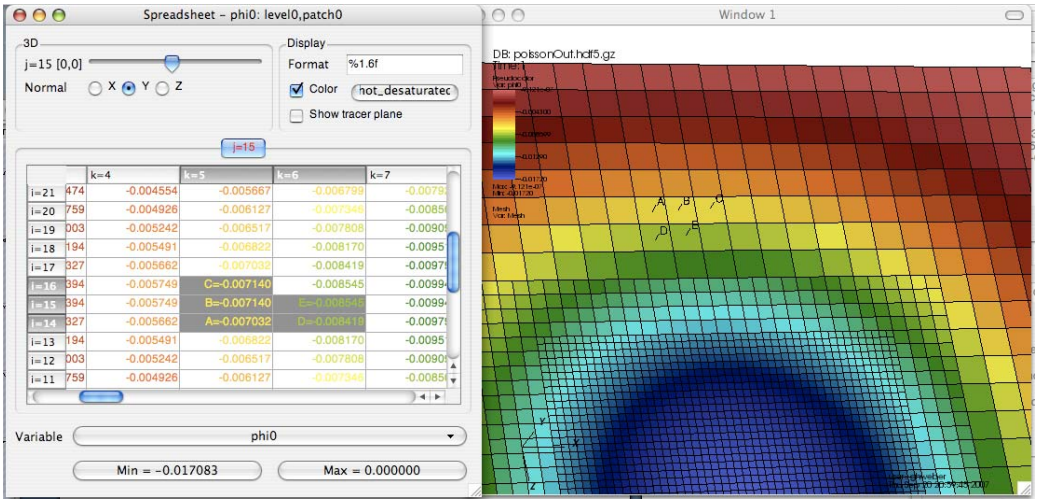

Figure 2: Spreadsheet plots are an important tool for debugging AMR codes. They support direct viewing of numerical data in patch cells. VisIt labels selected cells both in Spreadsheet and 3D visualizations allowing users to recognize correspondences quickly and effectively. (Sample data courtesy of P. Colella and B. van Straalen, LBNL)

part of the simulation result. VisIt tags cells in coarse patches that are available at finer resolution as "ghost" cells, allowing AMR patches to retain their highly efficient native format as rectilinear grids. VisIt offers a rich set of production-quality functions, like pseudocolor and volume rendering plots (Figure 1), for visualization and analysis of complex data sets on parallel platforms, making it an ideal candidate to replace specialized AMR visualization tools.

The majority of our work focused on implementing a set of essential debugging features offered by ChomboVis in VisIt. These efforts improve VisIt's handling of AMR data, both in terms of interface and performance. To date, the SciDAC Applied Partial Differential Equations Software Infrastructure Center (APDEC) has begun to transition away from their in-house ChomboVis application to VisIt.

Interface Enhancements

ChomboVis provides spreadsheet "plots" that support direct viewing of numerical values on a particular slice of a patch. This function is essential for debugging and used by AMR code development teams on a daily basis. We added these spreadsheets to VisIt, see Figure 2, and connected them to VisIt's "pick cell" feature, allowing users to "link" them to other plots.

We further added a capability to create new buttons in the VisIt interface. This matches a capability that APDEC users valued in ChomboVis and allows new users to quickly navigate the tool.

We also modified the VisIt selection routines to better support AMR data, allowing users to specify selections in terms of cell indices in a particular AMR level.

Performance Enhancements

We optimized handling of AMR grids in VisIt. These optimizations can save on memory by a factor of ten and also support more efficient rendering. Additional performance and memory optimizations improve efficiency for the important use case of rendering patch boundaries. VisIt previously used very general algorithm that was unnecessarily slow. Our new, specialized algorithm is an order of magnitude faster and more memory efficient.

Publications

Hank Childs. "Architectural Challenges and Solutions for Petascale Postprocessing" In Journal of Physics, Conference Series, Volume 78, June 2007.

G.H. Weber, V. Beckner, H. Childs, T. Ligocki, M. Miller, B. van Straalen, E.W. Bethel. "Visualization Tools for Adaptive Mesh Refinement Data." In: *Proceedings of the 4th High End Visualization Workshop* (Tyrol Austria, June 18-22, 2007), pp. 12-25, 2007.

For further information on this subject contact:

Name: Gunther H. Weber.
Organization: Lawrence Berkeley National Laboratory.
Email: ghweber@lbl.gov
Phone: (510) 486-5871

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