3-D Interactive Visualization with ACuTEMan

Dave Yuen ,Megan Damon, (1), Masanori C. Kameyama, (3), Michael Knox (2) , David H. Porter, Erik O. D. Sevre (1) .

1. Department of Geology and Geophysics and Minnesota Supercomputing Institute, University of Minnesota, Minneapolis, Minnesota 55455, USA

2. Laboratory of Computational Sciences and Engineering, University of Minnesota, Minneapolis, Minnesota 55455, USA

3. The Earth Simulator Center, Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa, Yokohama, 236-0001, Japan

Abstract

Mantle convection researchers at the University of Minnesota (UofM) have collaborated with members of the Laboratory for Computational Science and Engineering (LCSE) to implement a system capable of interactive exploration of large scientific model data sets rendering in near real time. Model data that is computed over hundreds of processors on a Linux cluster is sent over a local network to the LCSE lab on a periodic basis for visualization on an extremely high definition display. We describe the technical details involved in designing such a system and describe the specific application to the mantle convection simulation program, ACuTEMan.

Additional Keywords: 3-D volume visualization, mantle convection, interactive visualization, parallel computing.

1 Introduction

Our task has been to develop interactive visualization capabilities for high-resolution 3-D flows that are being computed in near real time on the Blade Cluster at the UofM. Here, we differentiate interactive from real-time visualization as possessing the ability to manipulate the visual representation of the data and having those changes available for assessment in a timely manner. In our case, we are viewing 3-D results from the ACuTEMan model in near real-time (very close to the actual computation time), and we also have the ability, through specialized software, to adjust the rendering of our image and the color spectrum to explore additional areas of geophysical interest. Here we discuss the techniques employed to allow for instant feedback in the form of visualization rather than having to manually post process our results.

2 Strategy

The AcuTEMan model [1], a multigrid-based mantle convection simulation code, has been modified to use LCSE's interactive rendering system. Model data that is initially calculated at the BladeCenter is transferred over a local network in the Brick of Bytes (BoB) format to the LCSE for visualization [2]. After the data is transferred, it is rendered and then displayed over 13 million pixels on the LCSE's 10-panel PowerWall display. The transfer and rendering tasks operate in an automated fashion, allowing the ACuTEMan model to periodically and asynchronously send data over the local network for visualization. Figure 1. Shows the steps involved in the process of using the LCSE rendering system from the BladeCenter. Researchers, who have access to PowerWall, whether physically or by other means such as a Web Cam, can observe the temperature fields of the ACuTEMan evolving over time on the Blade system.

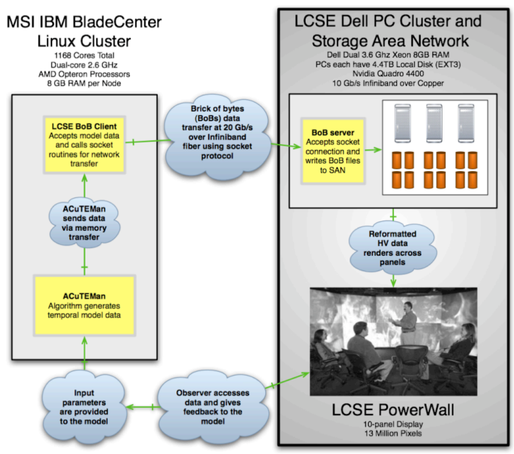

Figure 1. Model data is computed over N PEs at the Blad Center and is sent to a local BoB client where it is transferred to the LCSE. Once the data is received by the LCSE it is reformatted into the HV standard and is rendered as a three dimensional volume.

2.1 LCSE rendering system

To support interactive visualization, the LCSE has modified the rendering cluster to act as a data pipeline. Eleven visualization nodes are used to operate LCSE's PowerWall; each, a Dell workstation with 8 Gigabytes of RAM, an NVidia Quadro graphic board, and a high-speed connection to a multi-Terabyte striped disk system. To achieve fast transfer rates, incoming model data is stored on a ram disk and is periodically deleted; the speed of the disk writes is 125 MB/s, while the virtual ram disk allows for up to 1GB/ sec. When model data reaches the LCSE, it is converted from the BoB files to a single HV file for volume rendering. A HV file contains a single time step of data restructured in a tree hierarchy [3]. After the HV file is created, a MPI program broadcasts this file to each of the visualization nodes over Infiniband so that rendering can begin. The time between model time steps can be used to manually explore data using the LCSE DSCVR software package, thus allowing for interactive visualization. The rendered image can either be displayed by the PowerWall (13 Megapixels.), sent back over the socket to DSCVR which is running on a Windows PC, or posted to a website. Some adjustments we make during this time are swapping colormaps, rotating the volume, and changing the opacity to view data that might otherwise be occluded.

3 DISCUSSION

The ACuTEMan code is a high-performance numerical tool, written for large-scale parallel computing in order to investigate the convective motions of the Earth's mantle [4]. ACuTEMan solves a set of linear elliptic equations for velocity and pressure using a multigrid method together with the smoothing algorithm named ACuTE. With this new capability, researchers using ACuTEMan have the ability to directly interact with live model data by rotating the volume, adjusting the color scale, and zooming into the data set for exploration of small-scale features. Undesired results due to incorrect model configuration can become visible to the researcher during the interactive visualization, thus allowing the calculation to be stopped preemptively, adjusted, and then restarted. In Figure 2 we show a series of camera snapshots of data being rendered interactively on the PowerWall. Shown in these images are red upwellings originating from the hot thermal layer at the bottom (roughly equivalent to 2700 km in depth inside the Earth) of the grid space. The blue areas are colder downwellings that provide the mass for a downward flow, thus initiating the convection

4 CONCLUSIONS & FUTURE WORK

Using ACuTEMan with interactive visualization, we can detect whether the model as been given insufficient input parameters and decide to terminate the execution of the model. This, in effect, allows the model results to be assessed more quickly, saves CPU hours and resources, and also minimizes wasted effort. Using these methods, we also learn a great deal by monitoring the evolution of 3-D mantle convection from the onset of the initial instabilities.

The interactive visualization system presented here offers a solution to support a variety of interactive supercomputing tasks both from the University of Minnesota and from remote sites. Currently, we have the ability to convert raw model data into an interpretable visualization, save the data in a variety of formats, and offer a service to both view and steer a computation. We are proposing a system that will offer these services in a web-based environment so that they can be accessed from outside the university.

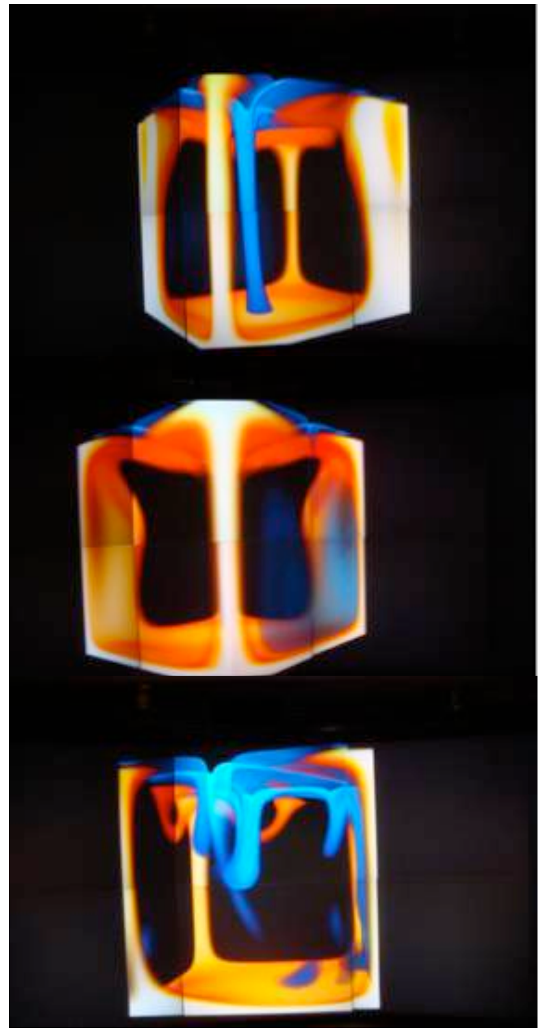

Figure 2. A series of camera snapshots taken of the LCSE PowerWall showing a three-dimensional temperature field from the ACuTEMan evolving in real-time with a Rayleigh number of 10^6.

REFERENCES

[1] M. Kameyama. ACuTEMan: A multigrid-based mantle convection sim-ulation code and its optimization to the Earth Simulator. Journal of the Earth Simulator, 4:2–10, 2005.

[2] K. Chin-Purchell, K. BOB-Brick Of Bytes, University of Minnesota Army High Performance Computing Research Center, 1995.

[3] H. Porter. Volume Visualization of High Resolution Data Using PC-Clusters. http://www.lcse.umn.edu/hvr/pc_vol_rend_L.pdf, 2006.

[4] M. Kameyama, A. Kageyama, & T. Sato. Multigrid iterative algorithm using pseudo-compressibility for three-dimensional mantle convection with strongly variable viscosity. J. Comput. Phys., 206(1):162–181, 2005.