The VolumePro Volume Rendering Cluster:
A Vital Component of Parallel End-to-End Solution

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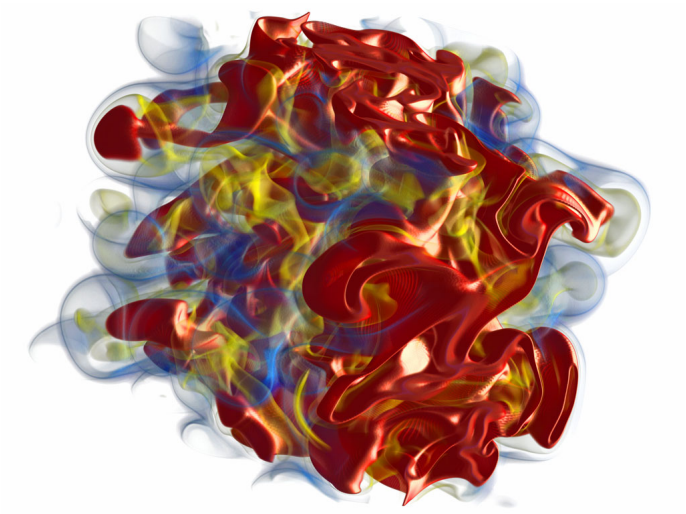
As data sets, both acquired from scanners and those generated from complex simulations, grow in size and complexity, researchers continue to push the boundaries of the amount of data that can be viewed, processed and analyzed interactively. It soon becomes clear that today's algorithms and systems must be scaled through the use of parallelism in order to create viable and cost effective solutions. But for parallelism to be most effective, it must be conceived and designed for efficiency through-out every individual component of the processing and computational pipeline. In fact, a parallel architecture must be preserved throughout the whole process in order to avoid single pipeline bottlenecks.

Sample applications that require this kind of infrastructure include the *TeraVoxel* project at Caltech (California Institute of Technology). Its goal is to capture and visualize actual turbulent fluid phenomena at the rate of 1024x1024x1024 bytes per second! Similarly, large fluid simulations are being performed on supercomputers both at Lawrence Livermore National Labs and Caltech. These simulations include reproducing and studying Rayleigh-Taylor instabilities sampled on a 256x256x1024 regular grid, with the newest data sets being as large as 512x512x2048 with 300-2000 time steps!



Our first challenge was the creation of a parallel environment capable of interactively rendering a single frame (time step) from one of these data sets. Our solution consisted of using 8 TeraRecon's VolumePro 500s on a 9 node cluster (8 rendering nodes and 1 display node), where each node renders 1/8 of the total volume, with the partial images being composited with HP-Compaq's Sepia technology in real-time. This allowed us to offer interactive volume rendering of a 512x512x512 volume at over 24 frames per second.

In keeping with our philosophy, our next challenge was to not only produce images in parallel, but to also display them on a parallel high-resolution monitor. Since most our users are scientists sitting at a desktop workstation we adopted IBM's T221 LCD (liquid crystal display), which has a resolution of 3840x2400 pixels, as our prototypical display. Feeding the T221's almost 10 million pixels is done via 4 DVI (digital visual interface) channels, that can be generated from 4 different sources, as long as they maintain a synchronized frame-rate (i.e. genlocking). We conceptualized and implemented the idea of "Desktop Interactive Remote Terascale Visualization" by creating a 5-node cluster equipped with graphics acceleration hardware (Radeon 8500), 1.2 tera-bytes of disk space each, and parallel Gbit connections to the outer world.

We have produced high-resolution (3840x2400) images for the TeraScale workstation using 4 TeraRecon's VolumePro 1000s, to produce 12 (4x3) 1024x1024 images of over 140 frames of a Rayleigh-Taylor simulation. The VolumePro 1000s allowed us to hold the complete 256x256x1024 volume in each card, while producing high-quality volume renderings, taking very little rendering time. These images were setup, produced and merged on 4 Pentium III nodes using NAG's IRIS Explorer, and then sent as 4 image stripes, 960x2400 pixels each, to the display nodes.

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For more information on the TeraVoxel project visit: *http://www.cacr.caltech.edu/projects/teravoxel/*
For more information on the Rayleigh-Taylor instability visit:
http://www.galcit.caltech.edu/Seminars/Fluids/PastFluids/1998-1999/Dimonte_G_abs.html
For more on the studies on the Rayleigh-Taylor instability refer:

¬ Cook, A. W., Dimotakis, P. E. *Transition stages of Rayleigh-Taylor instability between miscible fluids.* [Rayleigh-Taylor ABC runs] J. Fluid Mech. v.443, pp. 69–99. 2001.
¬ Cook, A. W., Zhou, Y. *Energy transfer in Rayleigh-Taylor instability.* [Rayleigh-Taylor 512^2x2048 runs]. Phys. Rev. E. v.66, p. 026312. 2002.

For more information of the fluids research being done at Caltech visit: *http://www.its.caltech.edu/~pxdgroup/*
For more information on Caltech's Desktop Interactive Remote Terascale Visualization visit:
http://viz.cacr.caltech.edu/projects/teraviz-workstation/.
For more on the TeraRecon's VolumePro products visit: *http://www.terarecon.com/products/volumepro_prod.html*
For more information on NAG's IRIS Explorer visit: *http://www.nag.co.uk/Welcome_IEC.html*
For more information on HP's Sepia compositing engine visit:
http://www.computer.org/proceedings/fccm/0375/03750146abs.htm or *http://www.sepiausers.org.*
For more on the VolumePro 500 cluster see:
http://www.cacr.caltech.edu/projects/ldviz/results/pvr/Lombeyda.PVG2001.pdf
For more information on IBM's T221 LCD visit: *http://www-132.ibm.com/webapp/wcs/stores/servlet/ProductDisplay?catalogId=-840&langId=-1&partNumber=9503DG3&storeId=1*

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