Vol-a-Tile - a Tool for Interactive Exploration of Large Volumetric Data on Scalable Tiled Displays

Nicholas Schwarz* Shalini Venkataraman† Luc Renambot* Naveen Krishnaprasad*
Venkatram Vishwanath* Jason Leigh* Andrew Johnson* Graham Kent‡ Atul Nayak‡

*Electronic Visualization Laboratory (EVL)
University of Illinois at Chicago (UIC)

†United Nations Environment Programme (UNEP)
Global Resource Information Database (GRID) - Sioux Falls

‡Institute of Geophysics and Planetary Physics (IGPP)
Scripps Institution of Oceanography (SIO)
University of California at San Diego (UCSD)

ABSTRACT

We present the current state of Vol-a-Tile, an interactive tool for exploring large volumetric data on scalable tiled displays. Vol-a-Tile presents a variety of features employed by scientists at the Scripps Institution of Oceanography on data collected from the Anatomy of a Ridge-Axis Discontinuity seismic experiment. Hardware texture mapping and level-of-detail techniques provide interactivity. A high-performance network protocol is used to connect remote data sources over high-bandwidth photonic networks.

1 INTRODUCTION

As the spatial size of volumetric datasets increase, scientists find it difficult to effectively examine data within the resolution constraints of single commodity displays. For example, scientists at the Institute of Geophysics and Planetary Physics (IGPP) at the Scripps Institution of Oceanography (SIO) located at the University of California at San Diego (UCSD) acquire large volumetric data from experiments such as the Anatomy of a Ridge-Axis Discontinuity (ARAD) seismic experiment [1]. This experiment collected a 3.2GB volume of seismic reflectivity across a twenty square kilometer area off the coast of Mexico along the East Pacific Ridge. The data reveals a large and complex magma chamber system where the ridge is misaligned. Scientists examining this data require the ability to view regions of interest at full resolution without losing context within the full dataset, view arbitrary slices through the data, use arbitrary cut-planes, probe the data at arbitrary positions, generate and view iso-surfaces based on probed values, and apply domain specific non-linear transfer functions interactively and in parallel. In such a situation a single desktop display is inadequate and high resolution tiled displays become necessary.

Vol-a-Tile [2] is an application designed to view large volumetric datasets on high-resolution, scalable tiled display walls like the thirty mega-pixel GeoWall2 [3] built at the Electronic Visualization Laboratory (EVL). The GeoWall2 consists of a tiled array of LCD panels, driven by a cluster of PCs, with high-end graphics cards, large disk space, dual processor CPUs and high-speed networking. The GeoWall2 is scalable because smaller or even larger versions can be built by adjusting the number of LCD panels and computers.

*e-mail: {schwarz|luc|naveen|venkat|spiff|aej}@evl.uic.edu
†e-mail: svenkataraman@usgs.gov
‡e-mail: {gkent|anayak}@ucsd.edu

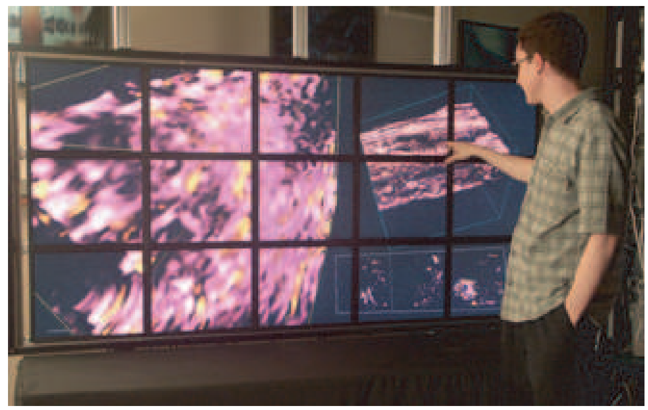

Figure 1: Vol-a-Tile displaying the ARAD seismic dataset.

Figure 1 shows Vol-a-Tile displaying the ARAD seismic experiment dataset on the GeoWall2 at EVL. Utilizing the OptIPuter [4] paradigm, this work in progress gives scientists the ability to roam through the entire remote dataset and display a small region of interest at its full resolution, gain context about the area surrounding the region of interest with a sub-sample view of the larger dataset, further explore the data with axis-aligned slices through the region of interest, and probe values from the full dataset at arbitrary locations. Level-of-detail (LOD) techniques and 3D texture mapping hardware provide adequate interactivity. The user sets simple color and opacity transfer functions via an interactive widget. The use of a high resolution tiled display becomes paramount for the simultaneous display of these features, and understanding of such large volumetric datasets.

2 SYSTEM OVERVIEW

Vol-a-Tile is a parallel application built over the MPICH [5], OpenGL [6], GLUT [7], nVidia CG Shader [8], QUANTA [9], and VTK [10] libraries. Figure 2 shows the overall system organization. A Vol-a-Tile process is started on each node of the cluster driving the tiled display using MPI. Each node driving a tile retrieves data via its network link, and renders only a partial image corresponding to its appropriate position on the tiled display using a reduced view frustum. Rendering is performed using OpenGL 3D texture mapping support provided by the graphics hardware.

The master node of the cluster driving the tiled display accepts user interaction. The commands are broadcast to all slave processes controlling the individual tiles, which re-render the image areas cor-

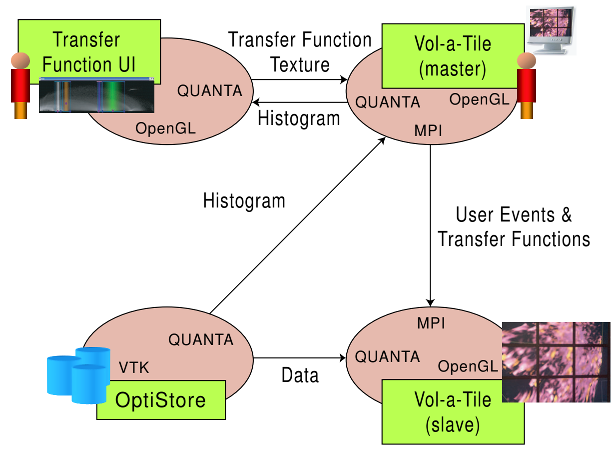

Figure 2: Vol-a-Tile System Overview.

responding to their tiles. Once each process renders its respective image, frame swap is performed in a synchronized fashion.

Vol-a-Tile provides a trackball interface to interactively scale, rotate, and pan any of the visual objects. When the user is interacting, the sampling rate decreases to reduce rendering time and allow interactivity. Once interaction is complete the sample rate inscreases, allowing automatic progressive refinement. Color and opacity transfer functions are selected with an interactive widget [11] and applied using the nVidia CG library.

OptiStore is the data management server that provides the high-performance I/O needed to stream data from storage to the nodes driving the tiled display over high-bandwidth photonic networks. It is designed to handle common data management operations, including loading data, maintaining meta-information about the data, such as dimension and scaling, and storing the results of resampled and cropped data. In addition, OptiStore provides data processing capabilities, including run time gradient/histogram generation, resampling, and cropping by utilizing functionality in VTK. Network connectivity is provided through the QUANTA network toolkit, which utilizes the aggressive network protocol, Reliable Blast UDP [12].

3 Conclusion and Future Work

We have presented Vol-a-Tile, an interactive exploration tool for large volumetric data on scalable tiled displays. SIO scientists employ Vol-a-Tile for geoscience applications involving volumetric data, such as the ARAD seismic experiment. Vol-a-Tiles features, which are continually evolving, have become a valuable tool for SIO scientists, aiding their exploration and understanding of large volumetric datasets.

In the future, we intend to provide users with arbitrarily oriented slices through the data, cut-planes, iso-surfaces based on probed values, and a sophisticated non-linear transfer function editor. To better serve the seismological community, we intend to adapt GPU based compression techniques [13] to maintain interactive frame rates with large time varying seismic datasets such as those in [14]. In order to better facilitate the examination of large remote datasets we are extending LambdaRAM [15] to operate on volumetric data. LamdbaRAM is a middle-ware used to harness high bandwidth network connectivity, and address latency issues associated with long haul networks by using distributed memory pools and aggressive pre-fetching schemes to cache data locally for large, distributed image viewing applications [16].

4 Acknowledgements

The advanced networking and visualization research, collaborations, and outreach programs at the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago are made possible by major funding from the National Science Foundation (NSF), awards EIA-9802090, EIA-0115809, ANI-9980480, ANI-0229642, ANI-9730202, ANI-0123399, ANI-0129527, EAR-0218918, as well as the NSF Information Technology Research (ITR) cooperative agreement (ANI-0225642) to the University of California San Diego (UCSD) for "The OptIPuter" and the NSF Partnerships for Advanced Computational Infrastructure (PACI) cooperative agreement (ACI-9619019) to the National Computational Science Alliance. EVL also receives funding from the US Department of Energy (DOE) ASCI VIEWS program and by the Office of Naval Research through an award from the Technology Research Education and Commercialization Center (TRECC). In addition, EVL receives funding from the State of Illinois, Microsoft Research, General Motors Research, and Pacific Interface on behalf of NTT Optical Network Systems Laboratory in Japan.

References

[1] G. Kent, S. Singh, A. Harding, M. Sinha, J. Orcutt, P. Barton, R. White, S. Bazin, R. Hobbs, C. Tong, and J. Pye. Evidence from Three-Dimensional Seismic Reflectivity Images for Enhanced Melt Supply Beneath Mid-Ocean-Ridge Discontinuities. *Nature*, 406:614–618, 2000.

[2] S. Venkataraman. Volume Rendering of Large Data for Scalable Displays Using Photonic Switching. Master's Project, University of Illinois at Chicago, 2004.

[3] The GeoWall2. http://www.evl.uic.edu/cavern/optiputer/geowall2.html.

[4] L. Smarr, A. Chien, T. DeFanti, J. Leigh, and P. Papadopoulos. The OptIPuter. *Communications of the ACM*, 46(11):58–67, 2003.

[5] MPICH Implementation of the Message Passing Interface. http://www-unix.mcs.anl.gov/mpi.

[6] OpenGL Cross Platform Graphics Library. http://www.opengl.org.

[7] GL Utility Toolkit. http://www.opengl.org/resource/libraries/glut.html.

[8] nVidia CG Shaders. http://www.cgshaders.org.

[9] E. He, J. Alimohideen, J. Eliason, N. Krishnaprasad, J. Leigh, O. Yu, and T. DeFanti. QUANTA: a Toolkit for High Performance Data Delivery Over Photonic Networks. *Future Generation Computer Systems*, 19(6):919–933, 2003.

[10] W. Schroeder, K. Martin, and B. Lorensen. *The Visualization Toolkit: An Object Oriented Approach to 3D Graphics*.

[11] J. Kniss, G. Kindlmann, and C. Hansen. Interactive Volume Rendering Using Multi-Dimensional Transfer Functions and Direct Manipulation Widgets. In *Proceedings of IEEE Visualization*, pages 255–262, 2001. Prentice Hall, 1998.

[12] E. He, J. Leigh, O. Yu, and T. DeFanti. Reliable Blast UDP: Predictable High Performance Bulk Data Transfer. In *Proceedings of the IEEE International Conference on Cluster Computing*, page 317, 2002.

[13] J. Schneider and R. Westermann. Compression Domain Volume Rendering. In *IEEE Visualization 2003*, pages 293–300, 2003.

[14] P. van Keken, J. Tromp, D. Komatitsch, S. Venkataraman, N. Schwarz, L. Renambot, and J. Leigh. Visualizing Seismic Wave Propagation. In *Eos Trans. American Geophysical Union, 84(46), Fall Meet. Suppl. Abstract ED31E-01*, 2003.

[15] C. Zhang, J. Leigh, T. DeFanti, M. Mazzucco, and R. Grossman. TeraScope: Distributed Visual Data Mining of Terascale Data Sets Over Photonic Networks. *Future Generation Computer Systems*, 19(6):935–943, 2003.

[16] N. Krishnaprasad, V. Vishwanath, S. Venkataraman, A. Rao, L. Renambot, J. Leigh, A. Johnson, and B. Davis. JuxtaView - a Tool for Interactive Visualization of Large Imagery on Scalable Tiled Displays. In *Proceedings of the IEEE International Conference on Cluster Computing*, 2004.