Simultaneous Interactive Visualization of Multiple Volumes

Zheng Li
Purdue University Rendering and Perceptualization Lab
West Lafayette, IN, USA 47907

Visualization of scientific data is critical to scientists and engineers who work with experiments and simulations that produce large volumes of raw numbers. Effective visualization methods allow them to intuitively understand their data far better than by studying the numbers or statistics. Furthermore, interactive visualization allows them to explore and learn about their data, perhaps grasping new details not known before. Volume visualization—the direct rendering of three-dimensional volumes—offers more information than simpler techniques, such as rendering of iso-surfaces. The simpler techniques can only convey a small portion of the vast amount of information contained in a volume, and they also potentially introduce artifacts [1]. However, there are several challenges to volume visualization, such as the engineering of useful display parameters, or *transfer functions* [2-4], finding optimizations to render volumes at smooth frame-rates [4-5,8], and providing useful and intuitive user interfaces [4,6-7].

This study focused on simultaneous visualization of volumetric data, i.e. rendering two or more three-dimensional functions at the same time in the same space. In addition, ways of improving user interaction was explored. These ideas are useful to researchers who wish to work with many pieces of data at a time, allowing them to integrate or contrast information from several sources. Rendering at interactive frame-rates allows researchers to manipulate their data in virtual reality as if they were touching it, opening up new avenues of exploration and understanding. Previous work in simultaneous visualization of multiple volumes focused mainly on improving display methodology to highlight relevant details effectively [4,8-9]. This study was less technical with respect to display methodology and graphics algorithm design, but focused more on interaction and utility.

This study used a hardware accelerated non-photorealistic volume renderer, the Interactive Volume Illustration System (IVIS), created at the Purdue University

Rendering and Perceptualization Lab, as a basis for a multiple volume interactive renderer. IVIS is optimized for the NVIDIA GeForce FX chipset, one seen on contemporary consumer graphics boards. IVIS uses hardware optimizations to do the majority of the rendering in hardware, taking advantage of GeForce FX's advanced texture features and programmable graphics processors. IVIS was extended to render up to four independent volumetric data sets simultaneously with independent viewing perspectives and transfer functions. The majority of the rendering was kept in hardware, allowing interactive frame rates.

IVIS's interactive interface was extended to allow independent rotation and translation of volumes, as well as interlinked manipulation of multiple volumes. This allowed volumes to be viewed side-by-side, rotated synchronously, and brought together or separated at will.

This work was used by two collaborators to satisfy specific visualization needs. The Purdue University Computation Catalysis and Materials Group used this system for the simultaneous visualization of multiple functions of molecules, such as wave functions, functions of wave functions, and electron potential distributions. A biologist at Purdue University used another extension of IVIS, which was developed with contributions from this study, to render visually and haptically Actin and Cofilin proteins in order to explore their bonding geometry.

[1] A. Kaufman, "Volume Visualization," International Spring School on Visualization, Bonn 2000.

[2] R. Moorhead and Z. Zhu, “Signal Processing Aspects of Scientific Visualization,” *IEEE Signal Processing Magazine*, vol. 12, no. 5, September 1995.

[3] J. Marks, B. Andalman, P. A. Beardsley, W. Freeman, S. Gibson, J. Hodgins, T. Kang, B. Mirtich, H. Pfister, W. Ruml, K. Ryall, J. Seims, and S. Shieber, “Design galleries: A general approach to setting parameters for computer graphics and animation," in *Proceedings of the 24th Annual Conference on Computer Graphics and Interactive Techniques*, pp. 389-400, ACM Press/Addison-Wesley Publishing Co., 1997.

[4] J. Kniss, G. Kindlmann, and C. Hansen, "Multidimensional Transfer Functions for Interactive Volume Rendering,” in *IEEE Transactions on Visualization and Computer Graphics*. July-September 2002. vol. 8, no. 3.

[5] K. Engel and T. Ertl, “Interactive High-Quality Volume Rendering with Flexible Consumer Graphics Hardware,” *EG 2002* State of the Art Report.

[6] R. S. Avila and L. M. Sobierajski, "A haptic interaction method for volume visualization," in *Visualization '96. Proceedings.* , 27 Oct.-1 Nov. 1996. Page(s): 197 -204, 485.

[7] I. M. K. van Mensvoort, “What you see is what you feel: Exploiting the dominance of the visual over the haptic domain to simulate force-feedback with cursor displacements," in *Proceedings of the Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, pp. 287-298, June 2002.

[8] A. Stompel, E. Lum, and M. Kwan-Liu, “Visualization of multidimensional, multivariate volume data using hardware-accelerated non-photorealistic rendering techniques," in *Computer Graphics and Applications, 2002. Proceedings. 10th Pacific Conference*, pp. 394-402, IEEE Computer Society Press, 2002.

[9] B. Wilson, E. Lum, and K.-L. Ma, “Interactive multi-volume visualization,” in *Workshop on Computer Graphics and Geometric Modeling, 2002 Conference on Computational Science*, 2002.